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*DRAFT Report*

# **Treatability Study Phase 1 Technical Memorandum**

## **Cooling Water Canal (SWMU No. 5) Peñuelas, Puerto Rico**

Prepared for

**Peñuelas Technology Park LLC  
Peñuelas, Puerto Rico**

(A Wholly Owned Subsidiary of The Dow Chemical Company)

EPA Facility I.D. No. PRD980594618

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**CH2MHILL**  
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# Acronyms and Abbreviations

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AASHTO	American Association of State Highway and Transportation Officials
ADCP	Acoustic Doppler Current Profiler
AET	apparent effects threshold
AOS	Apparent opening size
ASTM	American Society for Testing and Materials
AWQC	ambient water quality criterion
BERA	Baseline Ecological Risk Assessment
Bgs	below ground surface
CCME	Canadian Council of Ministers of the Environment
cm/d	centimeters per day
cm/sec	centimeters per second
cm <sup>2</sup> /sec	square centimeters per second
CPT	cone penetrometer testing
CWC	Cooling Water Canal
EPA	U.S. Environmental Protection Agency
EqP	Equilibrium Partitioning
ESV	ecological screening value
FCV	final chronic value
FEM	finite element modeling
g	gram
GC	Gas Chromatography
GPS	global positioning system
g/mL	grams per milliliter
HPLC	High Performance Liquid Chromatography
IDW	investigation-derived waste
ILFA	Industrial Landfill Area
K <sub>d</sub>	Partition Coefficient

kg/m <sup>2</sup>	kilograms per square meter
kHz	kilohertz
kn	Knot
kPa	Kilopascal
lb	pound
lb/ft <sup>2</sup>	pounds per square foot
lb/ft <sup>3</sup>	pounds per cubic foot
LOI	loss on ignition
m	meter
MARV	Maximum or Minimum Average Roll Value
mg/kg	milligrams per kilogram
mL	milliliter
mm/s	millimeters per second
mS/cm	milliSiemens per centimeter
msl	mean sea level
NADAS	Navigation and Data Acquisition System
ORP	oxidation-reduction potential
PDMS	Polydimethylsiloxane
ppt	parts per thousand
psi	pounds per square inch
PTPLLC	Peñuelas Technology Park LLC
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SLC	Screening Level Concentration
SM	silty sand
SP	poorly graded sand
SPME	semi-permeable micro extraction
SWMU	Solid Waste Management Unit
TOC	total organic carbon
TS	Treatability Study

UCCLLC	Union Carbide Caribe, LLC
USCS	Uniform Soil Classification System
WQS	water quality standard
°C	degrees Celsius
°F	degrees Fahrenheit
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µL	microliter
µm	micron



## SECTION 1

# Project Description

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This report summarizes the information collected during the Phase 1 field studies conducted in May 2009 at the Cooling Water Canal (Solid Waste Management Unit [SWMU] No. 5) at the Peñuelas Technology Park LLC (PTPLLC) site, formerly the Union Carbide Caribe, LLC (UCCLLC) site, located in Peñuelas, Puerto Rico. **Figure 1-1** presents a facility location map.

## 1.1 Background

UCCLLC operated a petrochemical manufacturing plant on the site from 1959 through 1985; the plant has since been decommissioned. The site includes a main plant process area (referred to as the Main Plant Area) where manufacturing and chemical processing facilities were located. Over the past 20 years, nearly all of the buildings, plant process equipment, and utility infrastructure systems on the plant site have been removed, demolished, or abandoned in place.

The manufacturing facility site occupied approximately 633 acres of low-lying land. While in operation, the plant produced olefins (ethylene and propylene), butadiene, polyethylene, aromatics (benzene, toluene, xylene, cumene), ethylene glycol ethers, butanol, acetone, phenol, and a phenolic derivative (bisphenol-A). Dripolene, commercially known as pyrolysis fuel, was produced as a byproduct residue of the furnace cracking reactions used to produce ethylene. The dripolene was removed from the production stream and disposed of in the Industrial Landfill Area (ILFA), which includes the Industrial Landfill (SWMU No. 20) and the Dripolene Pond (SWMU No. 15), located to the north of the Cooling Water Canal (CWC) (SWMU No. 5).

The CWC is designated as SWMU No. 5 in the Resource Conservation and Recovery Act (RCRA) Part B Permit for the facility because of the presence of contaminated sediments in the canal. Sediments in the CWC are contaminated mainly with semi-volatile organic compounds (SVOCs), including several polycyclic aromatic hydrocarbons (PAHs), as a result of past site operations. A U.S. Environmental Protection Agency (EPA)-approved Baseline Ecological Risk Assessment (BERA) conducted in 2005 (CH2M HILL, 2006) indicated that SVOCs in canal sediments could pose an elevated risk to ecological receptors, including protected species. A pre-final RCRA Facility Investigation (RFI) Report dated March 2011 (CH2M HILL, 2011a) was submitted to EPA.

## 1.2 Treatability Study

A Treatability Study (TS) was initiated to evaluate treatment and containment technologies being considered for the canal sediments, and to address whether the technologies can achieve agreed-upon remedial goals. A draft TS Work Plan (CH2M HILL, 2009a) was prepared to be consistent with the *RCRA Corrective Measures Study (CMS) Work Plan for Cooling Water Canal (SWMU No. 5)*, (CH2M HILL, 2008a), submitted to EPA on December 5, 2008. After comments were received from EPA and responses discussed, a draft final TS work plan was submitted in March 2011. The TS work plan describes the following Phase 1 and Phase 2 laboratory scale, bench scale, and field activities:

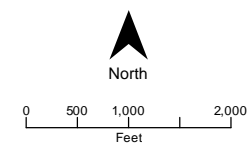


### Legend

- UCCLLC Property Boundary
- Facility Boundary

### Sources:

1. Sample Points: CH2M HILL, 2008
2. Aerials: USDA, 2007



**FIGURE 1-1**  
 Facility Location Map  
*SWMU No.5, Treatability Study Phase 1 Tech Memo*  
*PTPLLC, Peñuelas, Puerto Rico*

- Phase 1 field activities to obtain canal survey data, collect sediments and pore water samples to conduct the laboratory scale and bench scale studies, and to determine the groundwater flux in the CWC.
- Phase 2 field activities to evaluate construction feasibility of three types of caps and backfilling of a portion of canal. Pilot scale implementation of these technologies will provide better understanding of cap deployment issues such as proper placement of the cap, uniformity of the cap, scouring of cap material, armoring requirements, and sediment consolidation resulting from cap placement.

Data collected from these studies will be used to optimize design and operating conditions to support the remedy definition and selection processes. This report presents the data collected from Phase 1 field activities and bench scale studies.

## 1.3 CWC Site Description

The CWC is an open channel, a portion of which is navigable, running along the west side of the former manufacturing area of the PTPLLC site facility, and exiting to Tallaboa Bay to the south. **Figure 1-2** shows the SWMU No. 5 project location and layout. The canal is approximately 3,000 feet long and ranges in width from approximately 50 feet at the northern end to more than 300 feet at the southern end. The water depth of the canal normally ranges from less than 3 feet at the northern end to approximately 16 feet at the southern end. The canal banks are nearly vertical and are mostly vegetated by mangroves. Seasonal precipitation and tidal fluctuations control the direction and rate of flow in the canal. The canal is traversed by a paved vehicle bridge approximately 400 feet south of the northern end and by a pipe rack approximately 800 feet north of the southern end of the canal. The site topography in the vicinity is flat with little relief, with land surface elevations typically less than 10 feet above mean sea level (msl). Access to the canal is via a paved road and a boat dock along the eastern bank, and a vehicle bridge near the northern end.

## 1.4 Phase 1 Field Activities

Phase 1 studies were conducted as a part of the TS in 2009 and 2010,. Field activities were performed in May 2009, and bench scale studies were completed in August 2010.

### 1.4.1 Objectives

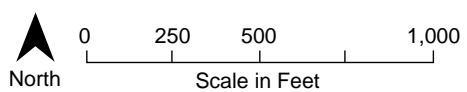
The objectives of the Phase 1 field activities are to collect data on:

- The current contamination levels in sediment and pore water in the area where caps and backfilling will be performed during Phase 2 field activities.
- The groundwater flux in the canal
- The geotechnical properties of the canal sediments
- The performance of the capping materials for site sediments and site water

### 1.4.2 Phase 1 Field Study Area Description

The Phase 1 field study area is located in the northern part of the CWC between transect 0+00 and 8+00, which is shallower and more contaminated than the southern part of CWC.





**FIGURE 1-2**  
 SWMU No. 5 Project Location  
*No.5, Treatability Study Phase 1 Tech Memo*  
*PTPLLC, Peñuelas, Puerto Rico*

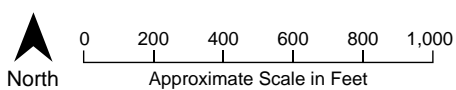
**Figure 1-3** shows Phase 1 project location. During the Phase 1 TS, sediment and pore water samples were collected from the area selected for phase 2 studies to conduct laboratory studies, geotechnical testing, and bench scale testing of capping material.

### 1.4.3 Phase 1 Subcontractors

The following subcontractors supported the Phase 1 field studies:

- CSA International Inc. (CSA), Stuart, FL, USA – sediment and pore water sampling, current profiling, side-scan sonar and bathymetric surveying, and sub-bottom profiling
- Underwater Marine, Peñuelas, PR – Work barge
- JFA, Aguadilla, PR – Support rig for cone Penetrometer Testing
- Zebra Environmental Corporation, Tampa, FL, USA – Cone Penetration Testing
- Lancaster Laboratories, Inc., Chicago, IL, USA – Analytical testing
- Kemron Environmental Services, Ashburn, VA, USA – Geotechnical testing
- University of New Hampshire, Durham, NH, USA – Sediment column studies and geotechnical testing





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<span style="border: 1px solid black; display: inline-block; width: 20px; height: 10px;"></span>	Phase 2 Activities

**FIGURE 1-3**  
Field Study Area  
*SWMU No. 5, Treatability Study Phase 1 Tech Memo*  
*PTPLLC, Peñuelas, Puerto Rico*

## SECTION 2

# Canal Surveys

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CH2M HILL sub-contracted CSA to assist Phase 1 field activities conducted from May 11 to May 22, 2009. CSA provided equipment and personnel to assist with marine surveying, current profiles, sediment and pore water sampling, and seepage meter deployment. **Figure 2-1** shows the canal survey area.

## 2.1 Acoustic Doppler Current Profiler

### 2.1.1 Purpose and Scope

An Acoustic Doppler Current Profiler (ADCP) was deployed to measure water current profiles in the canal for a range of water depths. The current profile data in the canal were collected to evaluate erosion and scouring potential of sediments and cap material, and to determine armoring requirements for caps.

### 2.1.2 Equipment

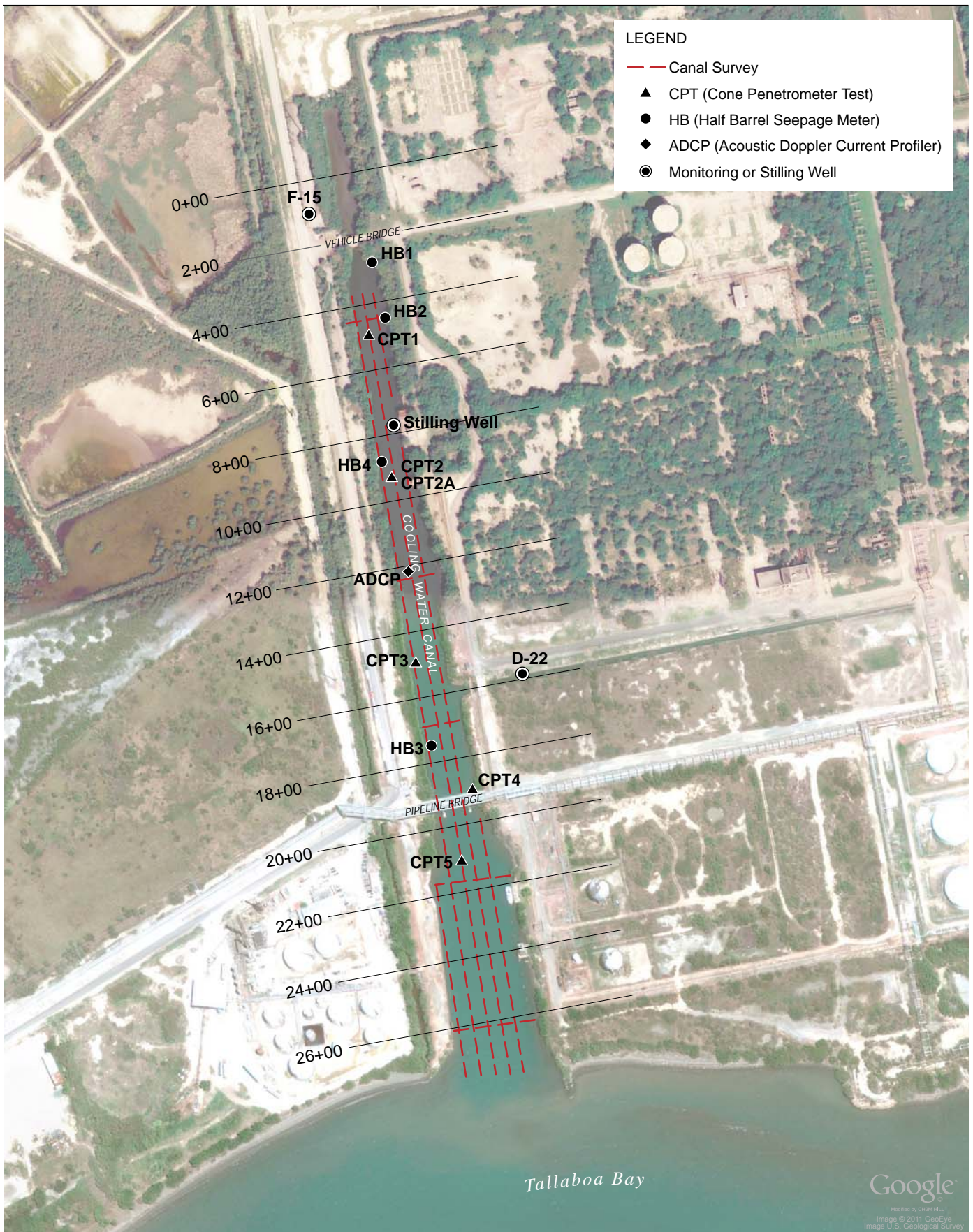
A Teledyne RDI Workhorse Mariner 1,200-kilohertz (kHz) ADCP was deployed approximately 1,000 feet south of the Vehicle Bridge and 700 feet north of the pipe rack bridge for 35 days to record water current speeds in the canal (CSA, 2009). Teledyne RDI Plan ADCP software was used to set bin size at 0.3 meter (m), with the first bin occurring at 0.7 m because of the blanking zone at the ADCP transducers. The ensemble interval (i.e., sampling rate) was set to 15 minutes. The ADCP data were processed with Teledyne RDI WinADCP software. Microsoft Windows® Office Excel 2003 was used to produce the final graphs (CSA, 2009).

### 2.1.3 Results

Water current profiles were obtained for near-bottom, mid-water, and near-surface of the canal as shown in **Figures 2-2** through **2-4**.

The CWC gradually narrows along its relatively short length and is enclosed on three sides. Current speeds within the canal were observed to be uniformly low. The highest current speeds were measured at mid-water depths (**Figure 2-3**) from May 14 to May 20. These higher current speeds were related to water released from the pump discharge pipe (**Figure 2-5**), located 275 ft north of the ADCP location. The discharge is angled downward and to the south (toward the ADCP). With the exception of these higher “spikes,” water current speeds at the near-bottom and mid-water levels in the canal averaged 35 millimeters per second (mm/s) (0.07 Knot (kn)). Near-surface current speeds averaged 40 mm/s (0.08 kn), except during ebb and flood tide stages, when current speeds as high as 100 mm/s (0.2 kn) occurred (CSA, 2009).





**FIGURE 2-1**

Survey Locations

*SWMU No. 5, Treatability Study Phase 1 Tech Memo  
PTPLLC, Peñuelas, Puerto Rico*

**CH2MHILL.**

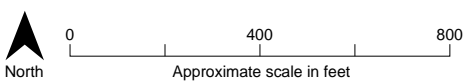




FIGURE 2-2

Water Current Profile for Near Bottom

*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*

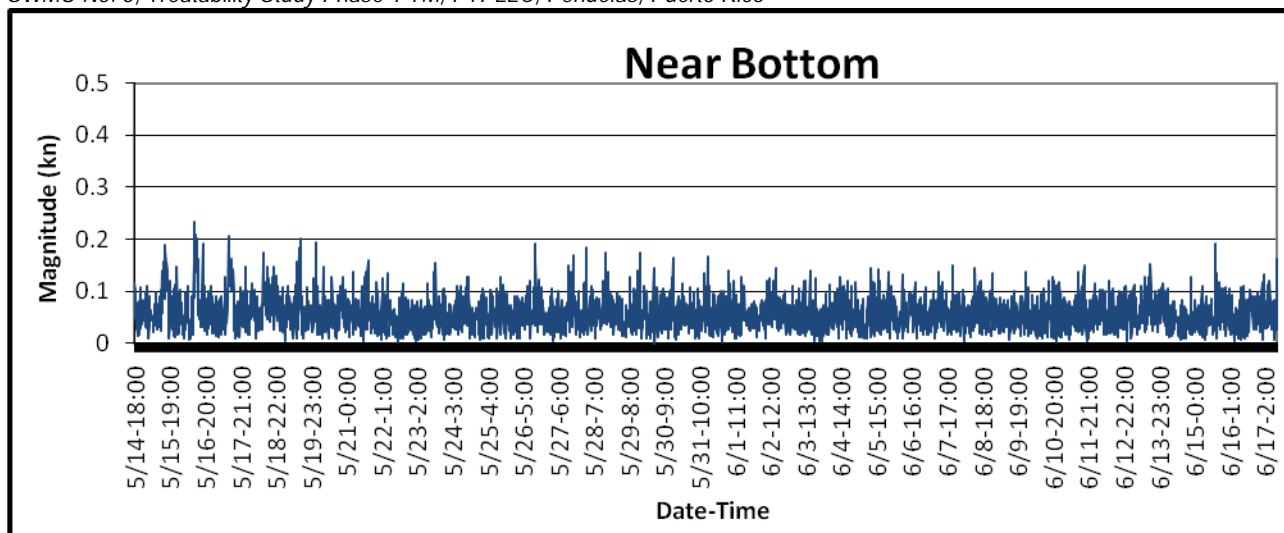


FIGURE 2-3

Water Current Profile for Mid Water

*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*

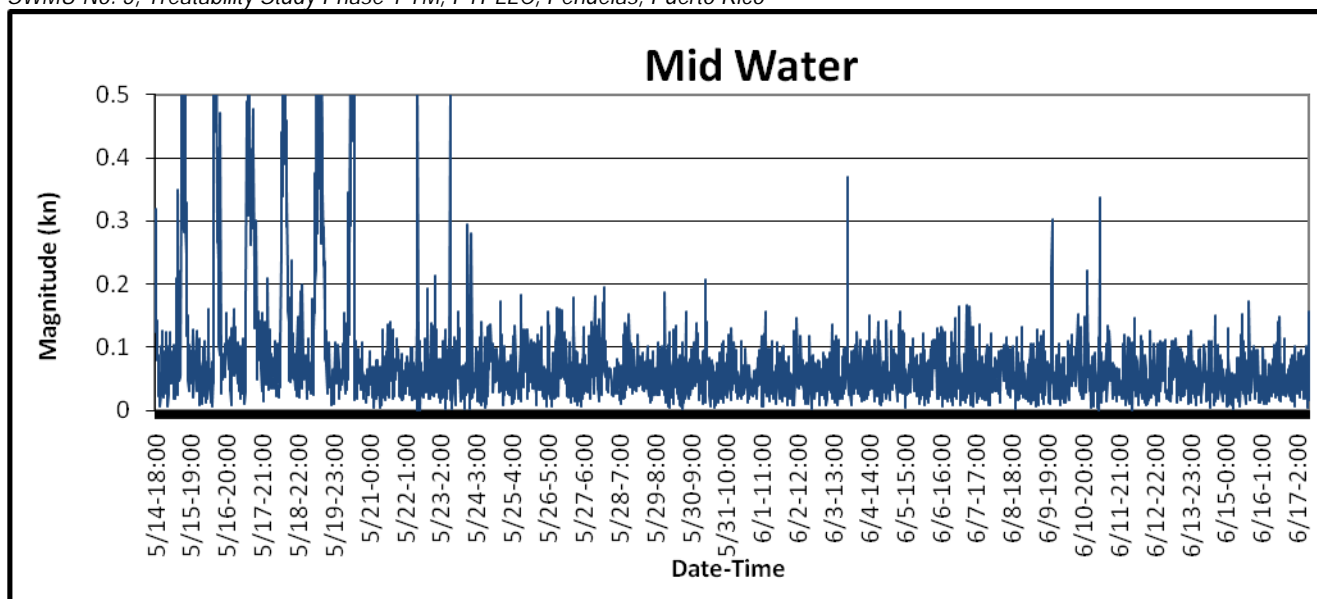


FIGURE 2-4  
Water Current Profile for Near Surface  
SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico

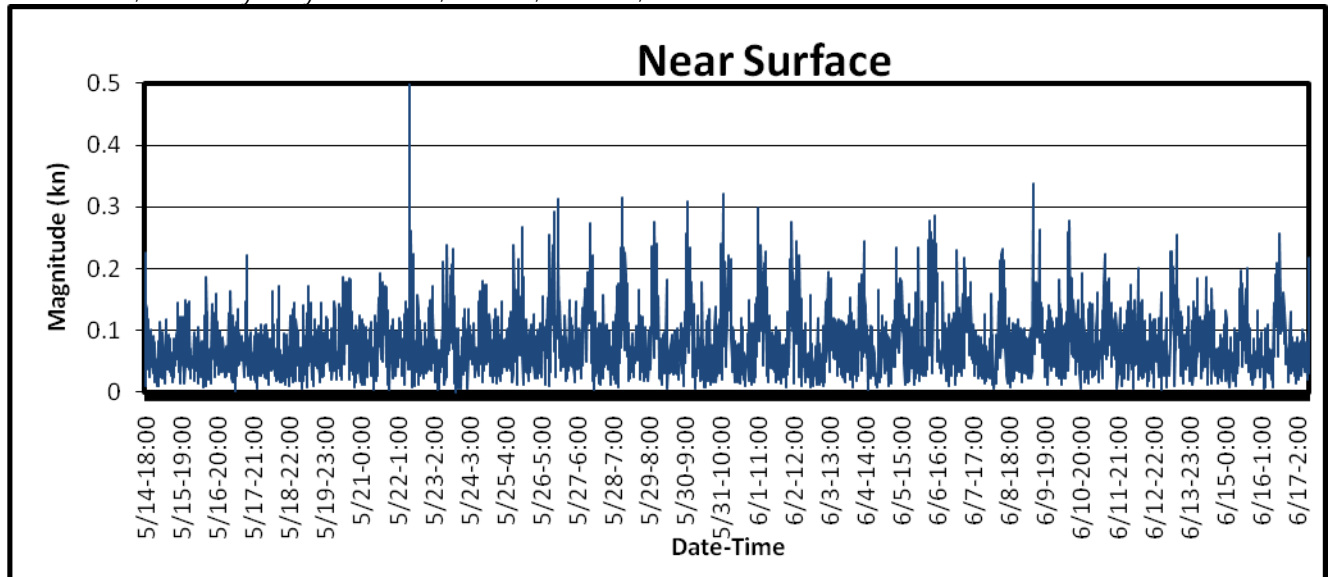


FIGURE 2-5  
Water Discharge from the Pump Discharge Pipe  
SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico



## 2.2 Side-Scan Sonar Survey

### 2.2.1 Purpose and Scope

A side-scan sonar survey was performed to define the sediment surface in the canal and to detect obstructions on the canal floor that may hinder cap installations. Side-scan sonar survey data supplement the bathymetric survey and provide higher resolution to provide cap deployment details.

## 2.2.2 Equipment

A Klein 3000 dual frequency digital imaging side-scan sonar system using Klein's SonarPro software was used to collect the required side-scan sonar data. The side-scan sonar system was interfaced with CSA's Navigation and Data Acquisition System (NADAS) to assist with vessel positioning during the field survey. Slant range for the side-scan survey was set at 25 m, with a resulting swath width of 50 m.

## 2.2.3 Results

Side-scan data were processed and analyzed to produce image files. The data for 100-kHz and 500-kHz frequencies were recorded, but only 500-kHz data were processed because of the higher resolution provided (CSA, 2009). The image files were merged to create a single mosaic image of the canal. **Figure 2-6** shows cap locations with side-scan sonar mosaic and bathymetric contours.

The images show that the middle of the canal is fairly flat and featureless for its entire length, with steep canal walls present along both sides. Features noted include the boat house bulkhead and pump areas, a small canal running west to east and perpendicular to the main canal, supports for the pipe rack bridge, and a prominent bottom feature on the west side of the canal south of the pipe rack bridge. This feature is a rise of approximately 6 feet above the surrounding bottom. Wooden pilings along the east side of the canal and the corrugated sheet piling along the west side of the canal were noted at the canal entrance.

## 2.3 Bathymetry Survey

### 2.3.1 Purpose and Scope

A bathymetric survey was performed to define underwater topography in the canal concurrent with the pilot studies. The updated depths are considered necessary to help plan the cap deployment process and selection of equipment.

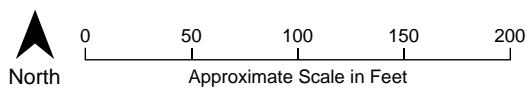
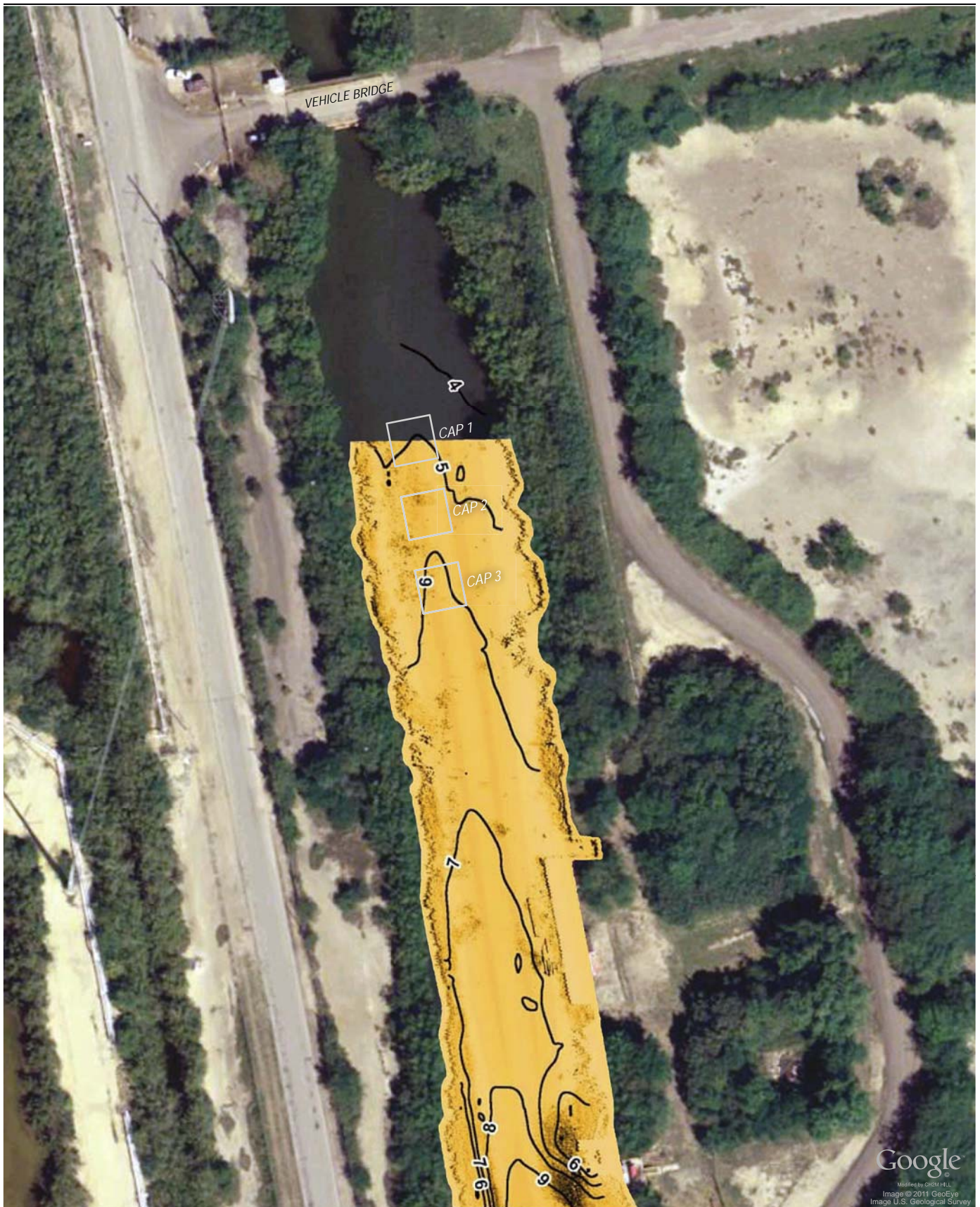
### 2.3.2 Equipment

An Odom Echotrac MK2 precision survey echosounder system was used to collect bathymetric data. A 200-kHz transducer was connected to the topside system to collect high-resolution depth data. The echosounder system was interfaced with CSA's NADAS to assist with vessel positioning during the bathymetric survey (CSA, 2009). In addition to bathymetric data collection during the sub-bottom and side-scan surveys, a separate bathymetry-only survey was conducted south of the pipe rack bridge and extending south of the canal entrance to produce a detailed contour plot of water depths at the canal entrance. The purpose of this plot was to estimate the amount of shoaling occurring across the canal at the opening into Tallaboa Bay (CSA, 2009).

### 2.3.3 Results

Bathymetric data were collected along the length of the canal and outside the entrance to the CWC. These bathymetric data were corrected for tide and adjusted to MSL. Tidal reductions were referenced from a site control point (3.08 feet msl) located on a concrete bulkhead near the boat house; the site control point was referenced to a local National Geodetic Survey monument. Tidal reductions were calculated from data collected with a MicroTide digital recording tide gauge installed on the concrete bulkhead 4.72 feet below the site control point.





**LEGEND**

□ Phase 2 Activities

**FIGURE 2-6**  
 Cap Array with Bathymetric Contours and  
 Side-Scan Sonar Mosaic  
*SWMU No. 5, Treatability Study Phase 1 Tech Memo*  
*PTPLLC, Peñuelas, Puerto Rico*

A correction offset of -1.64 feet was applied to correct the collected soundings to the msl vertical datum. Atmospheric pressure data were collected before the tide gauge deployment and were used to compute an atmospheric pressure average. An atmospheric pressure correction offset of -14.678 pounds per square inch (psi) was applied to compensate for atmospheric pressure. Atmospheric pressure data also were collected when the tide gauge was retrieved and these pressure data were compared against the correction offset.

Water depths in the northern end of the CWC range from 1 to 2.5 feet deep upstream of the vehicle bridge (CH2M HILL, 2006). With a few exceptions (i.e., the canal's steep sides, boat house, pumps, pipe rack bridge, and wooden pilings and outcrops), water depths in the canal increase from 2.5 feet at the vehicle bridge to 11 feet at the pipe rack bridge. The depth of the area between the pipe rack bridge and the canal entrance ranges from 18 feet to 20 feet. A shoal with water depth less than 5 feet was observed at the canal entrance; beyond this shoal, the water depths increase to greater than 20 feet entering into Tallaboa Bay (CSA, 2009). **Figure 2-6** shows cap locations with side-scan sonar mosaic and bathymetric contours.

## 2.4 Sub-bottom Profiling

### 2.4.1 Purpose and Scope

Sub-bottom profiling was performed to characterize the thickness of the softer sediments below the water/sediment interface and lying on top of the harder sediment substrates.

### 2.4.2 Equipment

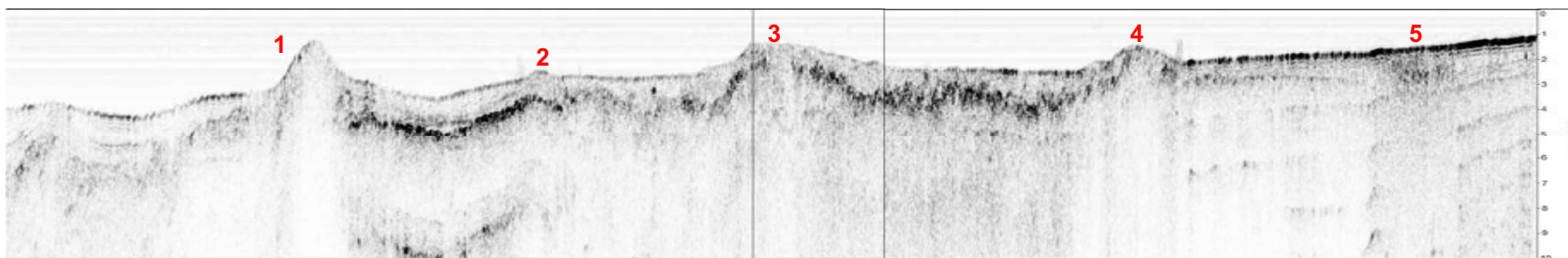
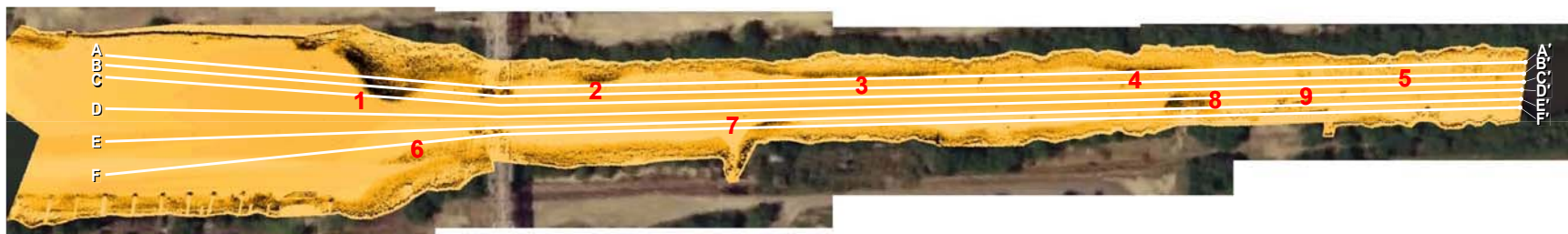
An Edgetech 216s Full Spectrum CHIRP sub-bottom profiling towfish and an Edgetech 3100P topside system were used to collect sub-bottom data within the canal (CSA, 2009). The sub-bottom profiling system was interfaced with CSA's NADAS to assist with vessel positioning during the field survey. A frequency spectrum of 2 to 15 kHz was used for collection of sub-bottom data.

### 2.4.3 Results

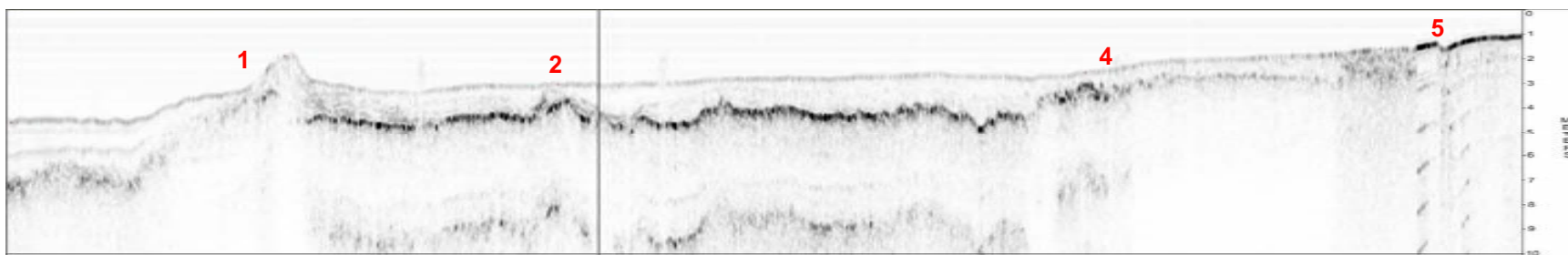
**Figures 2-7 and 2-8** present the sub-bottom data profile plots. **Figure 2-7** illustrates transects along the western side of the canal. Transect 1 runs very close to the western side of the canal and traverses five prominent shallow outcrops projecting from the canal bank. These outcrops have been identified in the side-scan sonar data. The first significant rise of the main reflector or primary consolidated sediment horizon was observed to be located on the west side of canal just before the pipe rack bridge (**Figure 2-7**). This main reflector (visible as a dark line on the side-scan sonar images) begins approximately 13 feet (4 m) below the water surface and 6.6 to 9.8 feet (2 to 3 m) below the canal bottom.

Once past this outcrop, the main reflector maintains a depth of approximately 3.3 feet (1 m) below the sediment-water interface throughout the canal, except at three bottom features along the west side of the canal also identified as outcrops in the side-scan sonar data. At each of these features, the main reflector rises and the thickness of the sediment layer above the main reflector decreases. Between the outcrops, sediment layers are visibly thicker. Just before the vehicle bridge, the main reflector rises to within less than 1 m of the canal bottom.

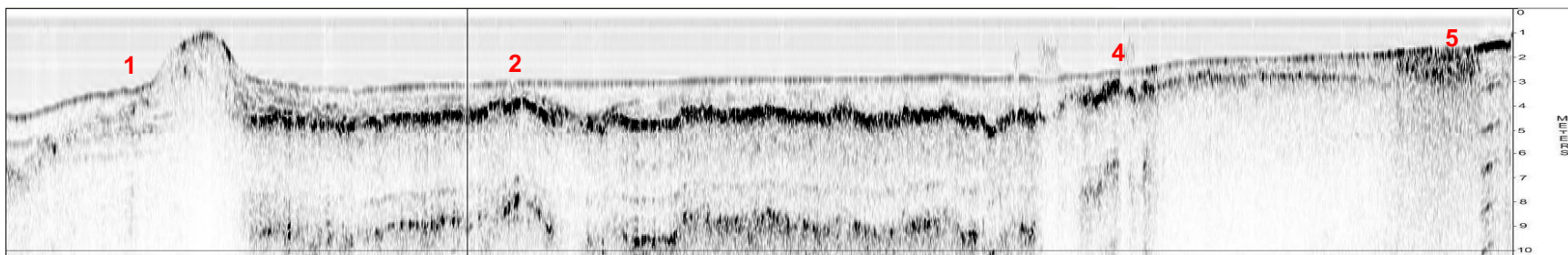




Transect A-A'



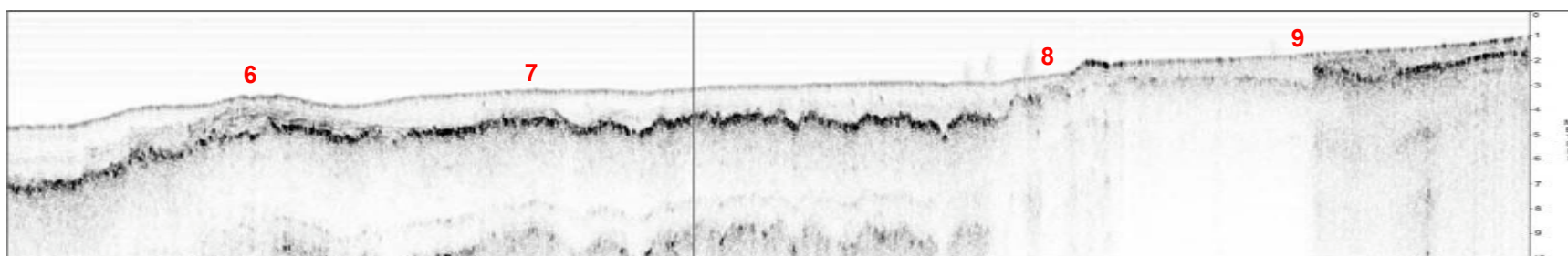
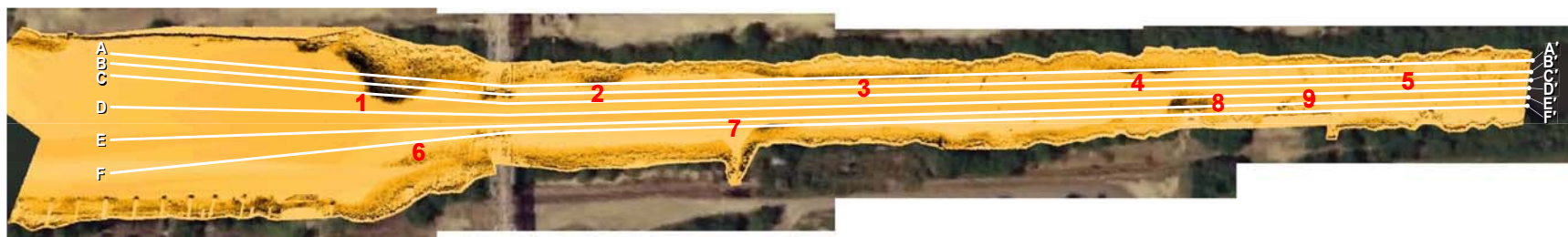
Transect B-B'



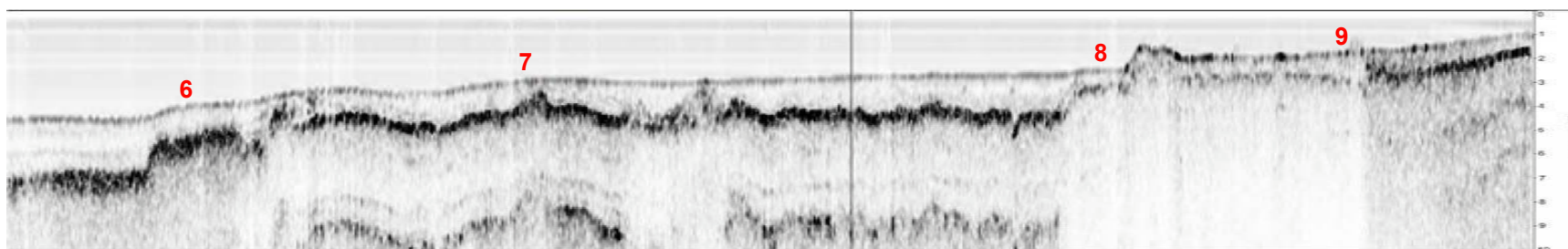
Transect C-C'

**Legend:** 1 through 7 = outcrops; 8 = pumps; 9 = boat house

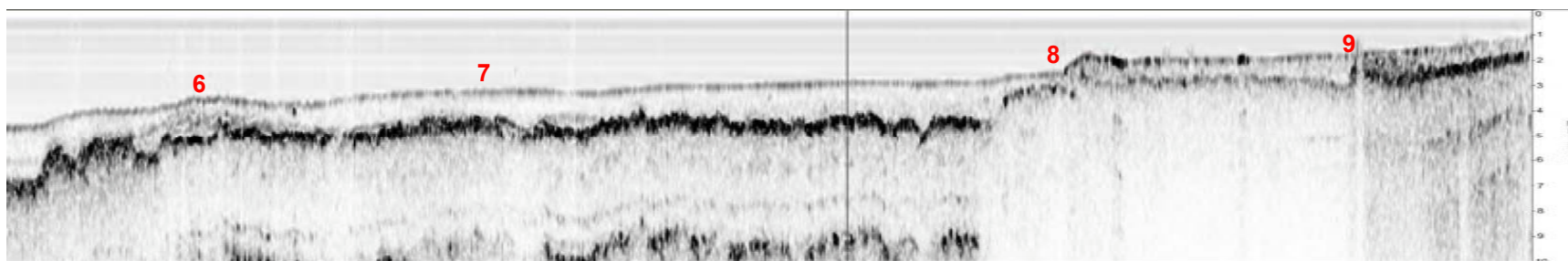
**FIGURE 2-7**  
Sub-bottom Profiles Collected from Transects A-A', B-B', and C-C'  
SWMU No. 5, Treatability Study Phase 1 Tech Memo  
PTPLLC, Peñuelas, Puerto Rico



Transect D-D' Canal Center Line



Transect E-E'



Transect F-F'

**Legend:** 1 through 7 = outcrops; 8 = pumps; 9 = boat house

**FIGURE 2-8**  
Sub-bottom Profiles Collected from Transects D-D', E-E', and F-F'  
SWMU No. 5, Treatability Study Phase 1 Tech Memo  
PTPLLC, Peñuelas, Puerto Rico

**Figure 2-8** illustrates transects along the center and eastern side of the canal. Prominent features include outcrops just south of the pipe rack bridge, an outcrop just north of the small side canal, a buildup of sediment at the discharge area at the pumps, and a smaller area next to the bulkhead at the boat house. Three distinct rises in the main reflector can be seen in the profiles, increasing from south to north along the canal until at the northern end of the canal less than 1 m of sediment is present above the main reflector.

## 2.5 Water Quality

### 2.5.1 Purpose and Scope

In-situ water quality parameters (pH, dissolved oxygen, oxidation-reduction potential [ORP], conductivity, salinity, and temperature) were measured by a water quality instrument (YSI 6920 multi parameter water quality sonde) towed behind the boat. Thus linear profiles of parameter variations were recorded. Variations in the water quality parameters along the canal could indicate anomalies such as fresh water inflow into the saltwater canal.

### 2.5.2 Equipment

The water quality sonde was towed from the boat house to the pipe rack bridge (north to south) and then from the pipe rack bridge back to the boathouse (south to north). The YSI water quality sonde data were imported into Microsoft Windows® Office Excel 2003 and graphs were created for each measured parameter.

### 2.5.3 Results

The CSA report (CSA, 2009) presented graphs for pH, salinity, temperature, dissolved oxygen and specific conductance. The profile data do not indicate anomalies that could be attributed to seeps within the canal. **Table 2-1** presents average values of the parameters.

TABLE 2-1  
Average Values of Water Quality Parameters  
Observed in the Canal on May 15, 2009  
SWMU No. 5, Treatability Study Phase 1 TM,  
PTPLLC, Peñuelas, Puerto Rico

Parameter	Average Value
pH	8.05
Temperature (°F)	83.22
Salinity (ppt)	36.53
Dissolved oxygen (mg/L)	4.89
Specific conductivity (mS/cm)	55.25

Notes:

mg/L – milligrams per liter

mS/cm – milliSiemens per centimeter

ppt – parts per thousand

°F – degrees Fahrenheit



# Field Sampling and Testing Procedures

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The proposed pilot study backfilling during Phase 2 field studies will be performed in the northernmost part of the CWC above the vehicle bridge between transects 0+00 and 2+00. The pilot scale evaluation of the capping alternatives (Reactive Core Mat™, AquaBlok™ cap, and sand cap) (also Phase 2) will be performed in the area between transects 4+00 to 8+00. The maximum water depth at transect 4+00 is reported to be approximately 5 feet, while at transect 8+00 the maximum depth is reported to be approximately 7 feet. During Phase 1, field activities were performed in these areas to collect data, samples for laboratory testing and evaluation, and general characteristics of the CWC cap and backfill areas to support Phase 2 pilot test studies. Sampling details are provided in the draft final TS Work Plan (CH2MHILL, 2011b), Sampling and Analysis Plan (CH2MHILL, 2009b), and CSA report (CSA, 2009). This section presents the purpose, equipment, and procedures for Phase 1 field activities. Results are presented in Section 6.

## 3.1 Sediment Sampling

### 3.1.1 Purpose and Scope

Sediment sampling was performed in the area designated for Phase 2 cap deployment between transects 4+00 and 8+00 and backfilling between transects 0+00 and 2+00. Sediment samples were collected as undisturbed cores and disturbed grab samples. Undisturbed sediment cores were collected for the geotechnical testing of sediments and for column studies of the capping materials. Disturbed grab samples were collected to determine the contamination levels in the sediments. Sample collection typically was within the top several feet of the sediment surface to characterize the sediments directly beneath the caps. **Table 3-1** provides sediment sampling details.

### 3.1.2 Equipment

A global positioning system (GPS) was used on the sampling boat and barge to determine core sampling position, using sampling station coordinates identified in Sampling and Analysis Plan (CH2MHILL, 2009). The GPS was positioned over the sampling location and sampling coordinates for each station were recorded in the field notes during collection, since site conditions sometimes warranted slight adjustments to sampling locations.

The water is too shallow in the northernmost portion of the CWC (north of the vehicle bridge) to allow use of a boat- or barge-mounted drill rig. These conditions required sampling of the first transect (0+00) by hand from a 12-foot long shallow draft boat.

Undisturbed sediment cores were collected for column studies (6-inch-diameter by 12-inch-long) and geotechnical testing (3-inch-diameter by 12-inch-long and 3-inch-diameter by 6-inch-long) using clear Tenite butyrate tubing. These tubes were pushed into the sediment with a coring instrument fitted with a manually-operated valve at the top. The valve was opened during pushing to allow escape of displaced air, and then closed during tube retrieval to create suction and “hold” the soft sample in the tube. Once the core tube was retrieved, it was capped at the bottom to retain the sample, removed from the coring instrument, and cut to size. The

undisturbed samples were securely taped, labeled, placed upright to maintain sample integrity, and shipped on ice in a plastic cooler to the laboratories. Disturbed sediment samples were collected from pilot study locations for backfilling and capping for chemical testing. **Figure 3-1** shows the sediment sampling locations.

Sand was collected from the Canarico Quarry in San Juan, Puerto Rico, in 5-gallon buckets, and shipped to the laboratory for testing. Chain-of-custody forms for laboratory samples are provided in **Appendix A**.

TABLE 3-1  
Sediment and Sand Sampling Details  
SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico

	Date	Sample ID	Latitude (N)	Longitude (W)	Sample length*(inches)	Diameter (inches)	Parameters
<b>Geotech Sampling (undisturbed cores)</b>							
SCU1	5/16/2009	05-SCU1	17°59.837'	66°44.834'	6	3	Moisture Content, Atterberg Limits, Organic Content
SCU2	5/16/2009	05-SCU2	17°59.790'	66°44.822'	6	3	Moisture Content, Atterberg Limits, Organic Content
SCU3	5/16/2009	05-SCU3	17°59.786'	66°44.824'	6	3	Moisture Content, Atterberg Limits, Organic Content
SCU4	5/16/2009	05-SCU4	17°59.778'	66°44.823'	6	3	Moisture Content, Atterberg Limits, Organic Content
<b>Analytical Sampling (disturbed samples**)</b>							
SCD1***	5/16/2009	05-SCD1	17°59.837'	66°44.834'	NA	NA	PAH, TOC, Elutriate
SCD2	5/16/2009	05-SCD2	17°59.790'	66°44.822'	NA	NA	PAH, TOC
SCD3	5/16/2009	05-SCD3	17°59.790'	66°44.822'	NA	NA	PAH, TOC
SCD4	5/16/2009	05-SCD4	17°59.784'	66°44.823'	NA	NA	PAH, TOC
SCD5	5/16/2009	05-SCD5	17°59.784'	66°44.823'	NA	NA	PAH, TOC
SCD6	5/16/2009	05-SCD6	17°59.778'	66°44.823'	NA	NA	PAH, TOC
SCD7	5/16/2009	05-SCD7	17°59.778'	66°44.823'	NA	NA	PAH, TOC
<b>Capping Studies Lab: Geotech Testing (undisturbed cores)</b>							
GT1	5/16/2009	05-GT1	17°59.786'	66°44.821'	12	3	Shear Strength, Permeability, Sediment Consolidation Testing
GT2	5/16/2009	05-GT2	17°59.783'	66°44.821'	12	3	Shear Strength, Permeability, Sediment Consolidation Testing

TABLE 3-1  
Sediment and Sand Sampling Details  
SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico

Date	Sample ID	Latitude (N)	Longitude (W)	Sample length*(inches)	Diameter (inches)	Parameters	
Capping Studies Lab: Column Testing (undisturbed cores)							
CS1	5/15/2009	05-CS1	17°59.790'	66°44.822'	12	6	Cap Performance Testing, Gas Ebullition Testing, Cap Model
CS2	5/16/2009	05-CS2	17°59.784'	66°44.823'	12	6	Cap Performance Testing, Gas Ebullition Testing, Cap Model
CS3	5/16/2009	05-CS3	17°59.778'	66°44.823'	12	6	Cap Performance Testing, Gas Ebullition Testing, Cap Model
Sand samples							
SS1	5/20/2009	05-SS1	NA	NA	NA	NA	Particle size analysis
SS2	5/20/2009	05-SS2	NA	NA	NA	NA	Particle size analysis
SS3	5/20/2009	05-SS3	NA	NA	NA	NA	Particle size analysis

Notes:

\*Core length shipped to the labs

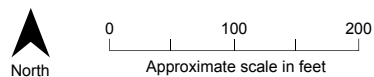
\*\*Disturbed sediment samples were collected from top 0-6 inches surface sediments

\*\*\*Sediment and site water for Elutriation collected from the same location as SCD1

NA = Not applicable



**FIGURE 3-1**  
 Sample Locations  
*SWMU No. 5, Treatability Study Phase 1 Tech Memo*  
*PTPLLC, Peñuelas, Puerto Rico*



Undisturbed sediment cores that were longer than required for testing were trimmed to 12 inches in length, sealed, and shipped. Unused sediment samples were treated as investigation-derived waste (IDW). Further details regarding the testing and analyses of these samples are provided later in this section; analytical and geotechnical results are provided in Section 6.

## 3.2 Pore Water Sampling

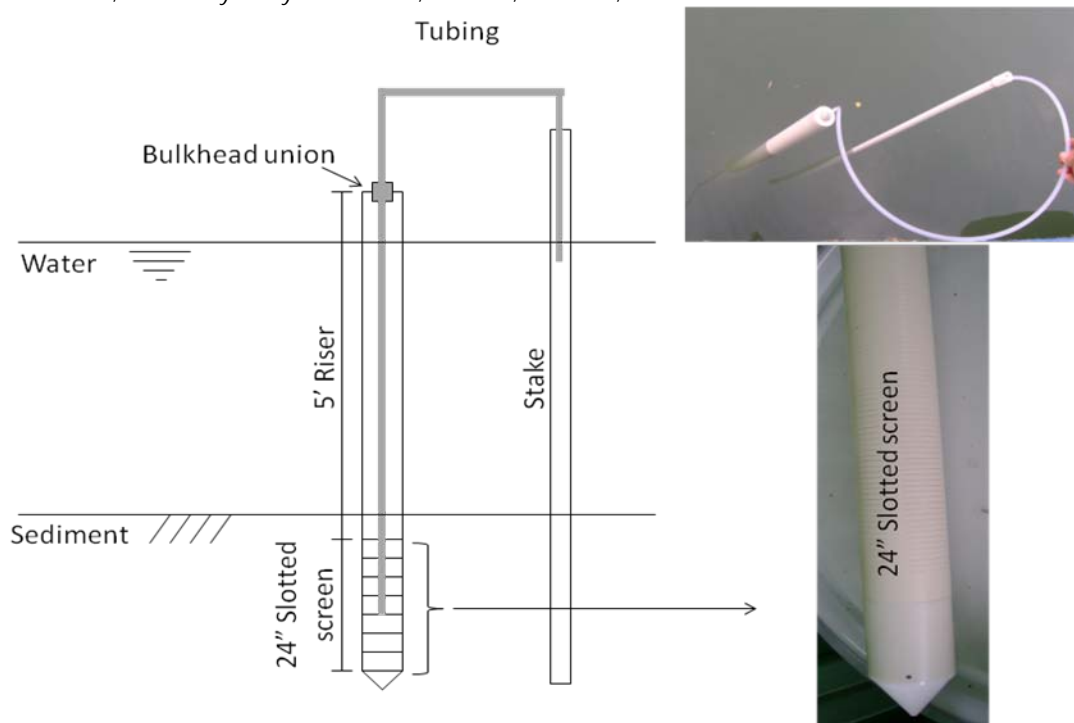
### 3.2.1 Purpose and Scope

Pore water samples were collected in the pilot scale capping and backfilling areas using push point samplers to evaluate contaminant concentrations in shallow sediments between transects T-2+00 and T-8+00, toward the northern part of the CWC. At least two samples were collected from each cap area to determine the PAH concentrations before the cap placement. The push points with 24-inch slotted screen were considered appropriate for collecting pore water samples within the upper 2 feet of canal sediment.

### 3.2.2 Equipment

The push points were deployed by hand into the sediment to sufficient depth to ensure that the screen or slots of the push point extended below the sediment surface. Dedicated tubing was connected to each push point prior to deployment to avoid cross-contamination with ambient water during installation. The tubing was extended above the water surface and was secured to a stake for future sampling. **Figure 3-2** shows push point sampler details.

**FIGURE 3-2**  
Push Point Samplers for Pore Water Sampling  
*SWMU No. 5, Treatability Study Phase 1 TM, PTP LLC, Peñuelas, Puerto Rico*



The tubing was connected to a peristaltic pump and each push point was purged prior to sample collection until pumped water was visibly clear. Purge volume was determined in the field based on point construction and tubing length and diameter. Purge water was handled as IDW. **Table 3-2** provides pore water sampling details.

TABLE 3-2  
Pore Water Sampling Details  
SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico

Station	Date	Sample ID	Latitude (N)	Longitude (W)	Water depth (ft)	Parameters
PW01	5/21/2009	05-PW1	17°59'48.0"	66°44'49.6"	4.4	pH, ORP, Alkalinity, Salinity, TOC, PAHs
PW03	5/21/2009	05-PW3	17°59'47.3"	66°44'49.4"	4.7	pH, ORP, Alkalinity, Salinity, TOC, Metals, PAHs
PW04	5/21/2009	05-PW4	17°59'47.4"	66°44'49.3"	4.6	pH, ORP, Alkalinity, Salinity, TOC, PAHs
PW05	5/20/2009	05-PW5	17°59'47.0"	66°44'49.5"	4.8	pH, ORP, Alkalinity, Salinity, TOC, PAHs
PW07	5/20/2009	05-PW7	17°59'46.8"	66°44'49.3"	5.1	pH, ORP, Alkalinity, Salinity, TOC, Metals, PAHs
PW08	5/20/2009	05-PW8	17°59'46.9"	66°44'49.1"	4.9	pH, ORP, Alkalinity, Salinity, TOC, PAHs
PW09	5/20/2009	05-PW9	17°59'46.7"	66°44'49.3"	5.2	pH, ORP, Alkalinity, Salinity, TOC, PAHs
PW10	5/20/2009	05-PW10	17°59'46.7"	66°44'49.1"	5.2	pH, ORP, Alkalinity, Salinity, TOC, PAHs
PW11	5/20/2009	05-PW11	17°59'46.3"	66°44'49.2"	6.3	pH, ORP, Alkalinity, Salinity, TOC, Metals, PAHs
PW12	5/20/2009	05-PW12	17°59'46.4"	66°44'49.1"	5.4	pH, ORP, Alkalinity, Salinity, TOC, PAHs
PW13	5/20/2009	05-PW13	17°59'45.9"	66°44'49.1"	6.3	pH, ORP, Alkalinity, Salinity, TOC, PAHs
PW14	5/20/2009	05-PW14	17°59'45.9"	66°44'49.0"	5.8	pH, ORP, Alkalinity, Salinity, TOC, PAHs
<b>**Pore water Sampling (for Centrifugation and analysis)</b>						
PW3	5/21/2009	05-PWC3	17°59'47.3"	66°44'49.4"	4.7	TOC, PAHs
PW7	5/20/2009	05-PWC7	17°59'46.8"	66°44'49.3"	5.1	TOC, PAHs
PW11	5/20/2009	05-PWC11	17°59'46.3"	66°44'49.2"	6.3	TOC, PAHs

Notes:

\* \*Pore water samples collected from the locations of PW-3, PW-7 and PW-11 were also centrifuged in the lab to determine any difference in TOC and PAHs results if samples are centrifuged.



NA = Not applicable

The pore water sampling coordinates were determined by CSA (CSA, 2009) when installed. Pore water sampling locations are shown on **Figure 3-1**. The analytical results for pore water are provided in Section 6.

## 3.3 Groundwater Flux Measurements

### 3.3.1 Purpose and Scope

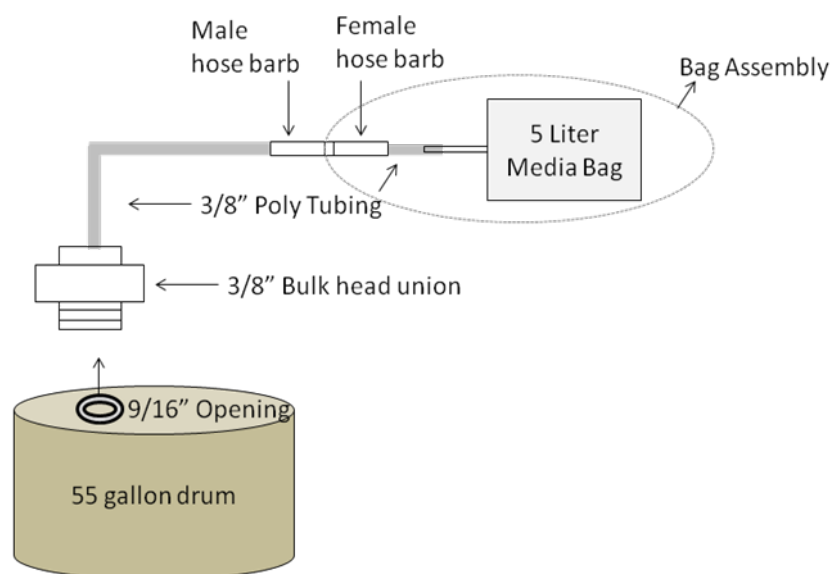
Seepage meters were deployed to measure the seepage of water across the sediment/water interface separating groundwater below the canal and surface water in the canal. Seepage meters provide data for groundwater flux in the canal that provides an advection rate at which contaminants can pass through the sediments and permeable portions of the cap.

### 3.3.2 Equipment

#### Seepage Meter Assembly

The (half-barrel) seepage meter consists of a 55-gallon drum cut in half so that each half is open at one end and closed at the other. An outlet vent is fitted to the closed end (lid) to allow a water collection bag to be attached with flexible tubing. **Figure 3-3** shows the seepage meter design. The seepage meters were deployed by inserting the open end down into the bottom sediments and allowing the water inside the meter to equilibrate with the surface water. The vent hole was then closed and a collection bag was attached to the outlet vent. Seepage flux was determined by measuring the amount of water entered the collection bag over 24 hours divided by the area of the base of the seepage meter.

**FIGURE 3-3**  
Seepage Meter Assembly  
*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*





### 3.3.3 Deployment Process

The depth of the canal where seepage meters were deployed varied from 3 ft to 8 feet and the sediments were soft. A flange was added to the lid of the 55-gallon drum to allow deployment from the boat with a riser, eliminating the need for divers. The seepage meters were pushed into the soft sediments with the help of risers fixed to the flange. Four sets of seepage meters were deployed into the canal as HB1, HB2, HB3, and HB4. **Table 3-3** provides deployment details. The first set of bag assemblies for HB1, HB2, and HB4 were deployed on May 18, 2009. After 24 hours, these bag assemblies for HB1, HB2, and HB4 were replaced and a first bag assembly was deployed for HB3 on May 19, 2009. After 24 hours the second set of bag assemblies for HB1, HB2, and HB4 and the first bag assembly for HB3 were detached and all the seepage meters were retrieved on May 20, 2009.

TABLE 3-3  
Half Barrel Seepage Meter Field Coordinates  
*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*

Station	Date	Water Depth (ft)	Latitude (N)	Longitude (W)
HB01	05/18/2009	3.1	17°59'48.9"	66°44'49.2"
HB02	05/18/2009	4.0	17°59'47.2"	66°44'48.8"
HB03	05/19/2009	8.3	17°59'34.4"	66°44'47.3"
HB04	05/19/2009	7.5	17°59'42.9"	66°44'48.9"

#### Notes

\*The survey coordinates for half barrel seepage meter were provided by CSA (CSA, 2009).

### 3.3.4 Testing Procedure

The bag assembly consists of 5-liter media bag, 3/8-inch poly tubing, and a female hose barb (**Figure 3-3**). The bag assemblies were weighed prior to attaching them to the seepage meters. Each bag assembly was attached to the end of the seepage meter outlet tube, making sure that no water was introduced to or lost from the meter. The time when the bag assembly was attached to the seepage meter was recorded in field notes.

After 24 hours, each collection bag was detached from the meter so as not to introduce or lose water. The time when each bag was detached from the meter was recorded.

Each bag was towel dried from the outside and then weighed. The volume change was calculated based on the weight (in grams [g]) of the water lost or gained and a unit weight of 1 gram per millimeter (g/mL). Seepage flux was calculated by dividing the volume change (mL) by the area of enclosed sediment (square centimeters [ $\text{cm}^2$ ]) by the time over which the volume change was measured (e.g., 24 hours). The resulting flux was recorded in units of  $\text{cm/hr}$ .

## 3.4 Cone Penetrometer Test

### 3.4.1 Purpose and Scope

A barge-mounted cone penetrometer test (CPT) rig was deployed by Zebra Environmental Corporation to obtain CPT data for subaqueous sediments in the canal, including tip pressure, sleeve friction, friction ratio, and pore pressure. From these measurements, in-situ physical properties of sediment were inferred, including classification, undrained shear strength, and pore pressure with depth.

### 3.4.2 Procedure

CPT tests were performed at five locations in the canal from the sediment surface to refusal for continuous data collection. Locations were selected to represent a variety of conditions along the canal, and at station 20+00 at the proposed cutoff wall location. The CPT was performed by pushing a rod-mounted cone vertically downward through the sediment to refusal while cone tip, sleeve, and pore pressures were measured continuously. The data were collected by real-time recording of signals and graphic logging on a laptop computer. Numerical and graphical data were recorded versus depth for vertical presentation of sediment parameters.

### 3.4.3 Equipment

The equipment used to conduct the CPT tests included:

- Geoprobe 5400 Track Unit
- Probe rods
- Data acquisition system
  - CPT controller unit
  - CPT100 Series GeoTech cone
  - 100-foot trunk lines
  - Laptop computer
- Barge
- Electrical generator

The barge work surface was 2.5 feet above the canal surface water level (**Figure 3-4**). The water depth in the canal where CPT was performed varied from 4.5 to 11.5 feet and the sediment thickness varied from 5 to 42 feet throughout the five locations. Test results are summarized in Section 6.

**FIGURE 3-4**

Geoprobe Unit for Cone Penetrometer Testing  
*SWMU No. 5, Treatability Study Phase 1 TM, PTP LLC, Peñuelas, Puerto Rico*



More details on the equipment and field activities and data collected are provided in the report submitted by Zebra Environmental Corporation (Zebra, 2009).

## 3.5 Surface Water and Groundwater Levels

### 3.5.1 Purpose and Scope

Canal water surface levels and adjacent groundwater surface levels were measured contemporaneously relative to the survey datum to estimate the differential head between groundwater and the canal surface water. The measurement included readings of the water surface in the canal and in nearby groundwater wells relative to a common vertical datum and local time system. The data were designed to indicate the magnitude and direction of differential head over time, including reversal of direction.

### 3.5.2 Equipment and Procedure

The station locations for measuring water levels were selected from available nearby monitor wells and included F-15 to the north and D-22 to the east of the CWC. A standpipe (polyvinyl chloride [PVC] pipe attached to boat dock and extending down into the water) provided a stilling well for a readily accessible point to measure the canal water surface level (**Figure 2-1**).

The equipment used to measure the water levels included Troll 700 recording transducers for timed readings of the canal and well water surfaces. A rain gauge was deployed to evaluate whether the CWC is affected by precipitation that may be experienced during the study. A stationary benchmark was installed to link these water surface elevations, the bathymetry and side-scan sonar surveys, and other field activities.

## SECTION 4

# Laboratory Procedures

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This section presents the procedures for laboratory testing. The specific sample collection methodologies for sediment and pore water chemistry sampling and geotechnical sampling are described in **Section 3**.

## 4.1 Analytical Testing

### 4.1.1 Sediment Analysis

Sediment samples were shipped to Lancaster Laboratories for analytical testing. The purposes of this testing were to evaluate concentrations of PAHs and general chemistry in backfill and cap test areas for bench and field scale capping studies, and to assist in development of a remedial alternative that prevents unacceptable levels of ecological exposure to SVOC-contaminated sediments in the canal. Samples for chemical analysis of sediment were collected in the proposed Phase 2 backfilling and capping areas of the CWC as shown in **Figure 3-1**. The following methods were used for sediment analyses:

- SW-846 method 8270C for PAH analysis
- Lloyd Kahn method for total organic carbon (TOC) analysis

Method details are provided in the TS Work Plan (CH2MHILL, 2009a; CH2M HILL, 2011). PAH concentrations and general chemistry results obtained from sediment samples are presented in **Section 6**. The analytical data quality report is provided in **Appendix B**.

### 4.1.2 Pore Water Analysis

Pore water samples were sent to Lancaster Laboratories for analytical testing for PAHs, metals, and general chemistry to evaluate the concentration and mobility of dissolved contaminants in the surface/groundwater system and capping/backfill system. The following methods were used for pore water analysis:

- SW-846 method 8270C for PAH analysis
- SW-846 method 6010B for metals analysis
- Method SM 20 5310C for TOC analysis
- Method 2320B for alkalinity

The method details are provided in the TS Work Plan (CH2MHILL, 2009a; CH2M HILL, 2011). Pore water data are presented in **Section 6**. The data quality report is provided in **Appendix B**.

## 4.2 Geotechnical Testing

Sediment samples from the backfilling and cap test area were sent to Kemron Environmental Services and the University of New Hampshire for geotechnical testing. Geotechnical data for the submerged sediments are required to evaluate the backfill and subaqueous capping technologies being considered. Physical and engineering properties characterized in the laboratory included strength (for stability and support of the cap/backfill), permeability (for

migration of pore water), and consolidation (for settlement of cap/backfill). Geotechnical properties of sediments include moisture content, Atterberg Limits and Loss on Ignition (LOI) (organic content); data for these properties are presented in **Section 6**. The following methods were used by Kemron for geotechnical testing:

- ASTM D2216 for moisture content
- ASTM D2974 for LOI
- ASTM D2166-06 for unconfined compressive strength
- ASTM D3080-04 for direct shear test
- ASTM D2435-04 for standard consolidation test
- ASTM D422 for particle size analysis of sand cap material
- ASTM D2487 for soil classification of sand cap material

In addition, specific gravity, seepage consolidation tests, and finite element of consolidation modeling (FEM) were performed on site sediment samples by the University of New Hampshire. The bench scale geotechnical testing details are provided in Section 5 and the sediment consolidation testing and FEM Report (Melton et al., 2009). The results of these analyses are provided in Section 6.

# Bench Scale Testing

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Bench scale testing was conducted at the University of New Hampshire to evaluate the efficacy of the capping materials for contaminated canal sediment and to determine related geotechnical properties of sediment. Environmental testing was performed to evaluate the effectiveness of three types of material, including:

- CETCO organoclay (PM-199) in a Reactive Core Mat™
- Aqua Technologies reactive material layer of organoclay (ET-1)
- Sand

## 5.1 Environmental Testing

### 5.1.1 Purpose and Scope

Undisturbed sediment cores and site water were shipped to the University of New Hampshire laboratory for the bench scale studies. The specific objectives of environmental testing were to evaluate:

- Adsorption capacities of capping material: To estimate the adsorption capacities of three types of capping material (CETCO PM-199, Aqua Technologies ET-1, and sand) for PAHs present in the site sediment pore water
- Performance of Caps: To evaluate the performance of three types of caps (CETCO Reactive Core Mat™, AquaBlok cap and sand cap) using column studies and 6-inch cores from the site
- Gas Ebullition Testing: To evaluate the gas ebullition potential for site sediments and visual inspection of gas ebullition caused by consolidation and warming of site sediments due to placement of capping material.
- Estimation of Life of the Caps: To predict the performance of the cap and estimate the effective life of the cap by using adsorption coefficients obtained from isotherm studies in a numerical model

### 5.1.2 Adsorption Capacity of Capping Materials

#### Description of Capping Materials

**CETCO Organoclay Reactive Core Mat™.** The Organoclay Reactive Core Mat™ is a permeable composite of geotextiles packed with organoclay, which is a non-swelling granular clay material that adsorbs oil and similar organics from water. In the organoclay Reactive Core Mat™ manufacturing process, fibers from the top needle punched nonwoven geotextile are needle punched through the organoclay media into a base needle punched nonwoven geotextile. There is no prescribed up or down orientation of Reactive Core mat™. As recommended by CETCO, however, it may be easier to unroll the Reactive Core Mat™ roll with the base (dark colored) geotextile facing upward during installation.

Geotextiles provide stability and physical isolation and the organoclay is the reactive material that adsorbs contaminants carried by advective or diffusive flow. The Reactive Core Mat™ provides a thinner cap than a traditional sand cap. **Table 5-1** presents the physical properties of organoclay and Reactive Core Mat™. The product specification sheet is provided in **Appendix C**.

TABLE 5-1  
Physical Properties of Organoclay and Reactive Core Mat™  
*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*

Properties	Test Method	Value
<b>Organoclay</b>		
Bulk Density Range	CETCO Test Method	44 – 56 lb/ft <sup>3</sup>
Oil Adsorption Capacity	CETCO Test Method	0.5 lb of oil per lb of organoclay, minimum
Quaternary Amine Content	CETCO Test Method	25 – 33% quaternary amine loading
<b>Finished Reactive Core Mat™ Product</b>		
Organoclay Mass per Area	CETCO Test Method	0.8 lb/ft <sup>2</sup>
Mat Grab Strength <sup>1</sup>	CETCO Test Method	90 lb MARV
Hydraulic Conductivity <sup>2</sup>	CETCO Test Method	1 x 10 <sup>-3</sup> cm/sec minimum

Notes:

<sup>1</sup>All tensile testing is performed in the machine direction.

<sup>2</sup> Permittivity at constant head of 2 inches and converted to hydraulic conductivity using Darcy's Law and Reactive Core Mat™ thickness per ASTM D5199 for geotextiles.

cm/sec – centimeters per second

lb – pound

lb/ft<sup>2</sup> – pounds per square foot

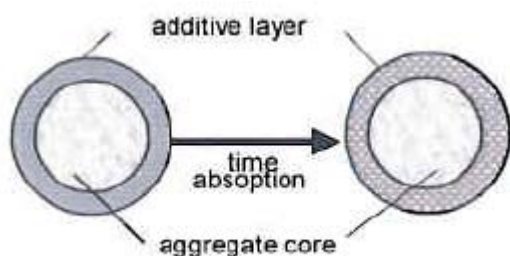
lb/ft<sup>3</sup> – pounds per cubic foot

MARV - Minimum Average Roll Value

**AquaBlok® Cap.** The AquaBlok cap system consists of a permeable reactive organoclay layer below a low-permeability capping layer to reduce advective flux and maximize the capacity of a relatively thin layer to adsorb or bind contaminants.

AquaBlok used ET-1 organoclay (manufactured by Aqua Technologies) to develop a calcium carbonate aggregate core encapsulated with a compacted 200-mesh pre-hydrated organoclay layer using composite aggregate technology. The ET-1 product was a 30/70 blend of organoclay and aggregate providing 2.1 lb of amendment per square foot of treatment for every 1 inch lift. The final product consists of a dense aggregate core coated with activated clay as shown in **Figure 5-1**.

FIGURE 5-1  
Configuration of Organoclay-coated Particle



*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*

Samples of this material were provided by AquaBlok to the University of New Hampshire to conduct bench scale studies. Table 5-2 presents the physical properties of the ET-1 material. The product specification sheet is provided in **Appendix C**.

TABLE 5-2  
Physical Properties of Aqua Technologies ET-1 Activated Clay  
*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*

Property	Value
Powdered	Approximate 200 Mesh
Oil adsorption capacity	50-100% by weight
Binder	Cellulosic polymer
Permeability	$1 \times 10^{-2}$ to $1 \times 10^{-5}$ cm/sec
Dry Bulk Density	75-85 lb/ft <sup>3</sup>
Moisture	10-20% (maximum)

Notes:

cm/sec – centimeters per second

lb/ft<sup>3</sup> – pounds per cubic foot

AquaBlok (3070 SW) provides the sequestration and isolation layer as well as a level of protection from surface water disturbances. AquaBlok<sup>®</sup> is a particulate material (similar to the organoclay-coated particle, but with each particle comprised of an aggregate core covered by a clay and polymer coating. The clay in most applications is primarily bentonite, and the polymer is added to promote adhesion between the clay and the aggregate core. The material generally is applied as a dry product through the water column to the surface of contaminated subaqueous sediments, and hydrates to form a continuous and impermeable isolation cap.

**Sand Cap.** The geotechnical properties of the sand material are provided in Section 6. **Figure 5-2** shows sand cap material.



FIGURE 5-2  
Sand Cap Material  
*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*



### Batch Experiments - Adsorption Kinetics

The objective of the adsorption kinetic study was to determine the kinetic rate of adsorption for targeted PAH compounds for three capping materials, including two types of organoclay and sand.

**CETCO organoclay:** Organoclay model PM-199, Lot# OB-031209, was supplied by CETCO Remediation Technologies. This is applied as a reactive material in the Reactive Core Mat™.

**Activated clay:** The second type of organoclay investigated was the Aqua Technologies activated clay ET-1, supplied by AquaBlok Composite Particle Systems.

**Sand:** The third type of capping material was quarry sand, SS-1, obtained by CH2M HILL from Canarico Quarry, San Juana Diaz, PR.

Each material was tested in triplicate at five points in time: 6 hours, 1 day, 2 days, 3 days and 7 days. Batch experiments were conducted with a solution prepared by spiking a methanol-based PAH stock solution into site water provided by CH2M HILL. Baseline characteristics of the site water were measured prior to the addition of PAH compounds to determine initial pH, temperature, and dissolved organic carbon concentrations as shown in **Table 5-3**. Experiment details are provided in the report submitted by the University of New Hampshire (Gardner et al., 2009).

TABLE 5-3  
Baseline Site Water Characteristics  
*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas,  
Puerto Rico*

Parameter	Value
Temperature	19.8 °C
pH	8.63
Dissolved Organic Carbon	6.05 mg/L

Notes:  
mg/L – milligrams per liter  
°C – degrees Celsius

Results of kinetic experiments are presented in Section 6.

### Batch Experiments - Adsorption Equilibrium

The objective of the adsorption equilibrium study is to determine the adsorption affinity of PAH compounds for the two organoclays and non reactive sand materials investigated in the kinetic study. Adsorbed mass of PAH compounds were quantified in relationship to the mass of total sorbent available.

Adsorption equilibrium testing was conducted with the same 14 PAH compounds examined in the kinetic experiments and for the same capping materials, (CETCO organoclay, AquaBlok organoclay, and SS-1 sand) in reverse osmosis (RO) water.

For adsorption studies, semi-permeable micro extraction (SPME) fibers were used to analyze PAH concentrations. SPME fibers were immersed at the start of the study and allowed to equilibrate with the aqueous concentrations. This is an accepted method for conducting adsorption studies such as these. The critical consideration is that the SPME fibers do not deplete the aqueous phase mass. SPME fibers are intended to measure the aqueous phase activity, and they do this by equilibrating with this phase while not significantly changing its activity. Experimental details are provided in the University of New Hampshire report (Gardner et al., 2009). The results of adsorption testing are provided in Section 6.

### 5.1.3 Performance of Capping Materials

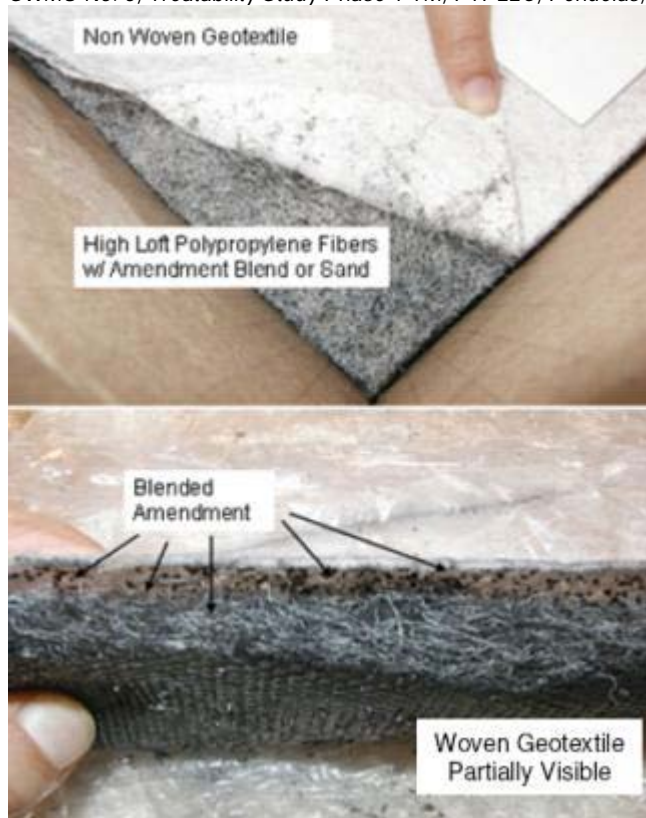
#### Objective

The objective of column studies was to determine the effectiveness of three cap alternatives using a constant flow column experiment. This study evaluated the effectiveness of a CETCO Reactive Core Mat™ filled with PM-199 organoclay, an AquaBlok reactive layer consisting of ET-1 organoclay, and a non-reactive sand cap.

The CETCO Reactive Core Mat™ consisted of two layers of geotextiles with polypropylene mesh between the two layers. The bottom geotextile layer consisted of 70-Apparent Opening Size (AOS) nonwoven geotextile fabric and the top layer consisted of 40 mesh woven geotextile. The organoclay (PM-99) was evenly distributed throughout the propylene fibers. The distributed amendment density of PM-199 was 0.8 lb/ft<sup>2</sup> (**Figure 5-3**).

The AquaBlok treatment system that was evaluated consisted of permeable reactive organoclay layer. AquaBlok organoclay was manufactured using composite aggregate technology composed of a calcium carbonate aggregate core encapsulated with a compacted 200-mesh pre-hydrated organoclay layer (**Figure 5-1**).

**FIGURE 5-3**  
CETCO Reactive Core Mat™  
*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*

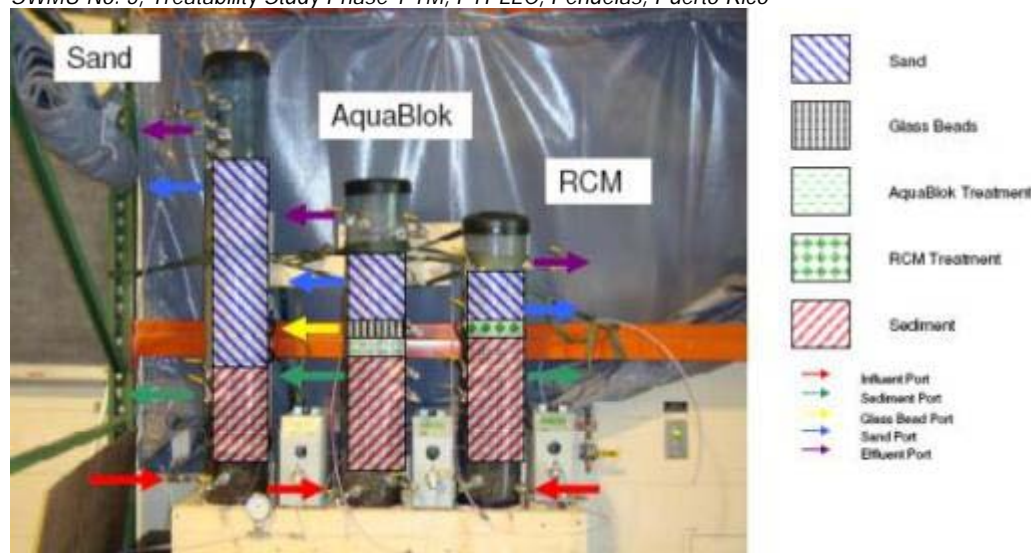


### Column test

Three undisturbed sediment cores (CS-1, CS-2, and CS-3) each 6 inches in diameter and 12 inches in length were used to simulate the site conditions for contaminant transport and loading. The column experiments were conducted in 6-inch-diameter clear PVC columns constructed by the university research group. These clear columns allowed visual inspection within the column during operating conditions. The column walls were lined by fluorinated ethylene propylene tape (RELTEK LLC) to provide an inert surface inside the column walls.

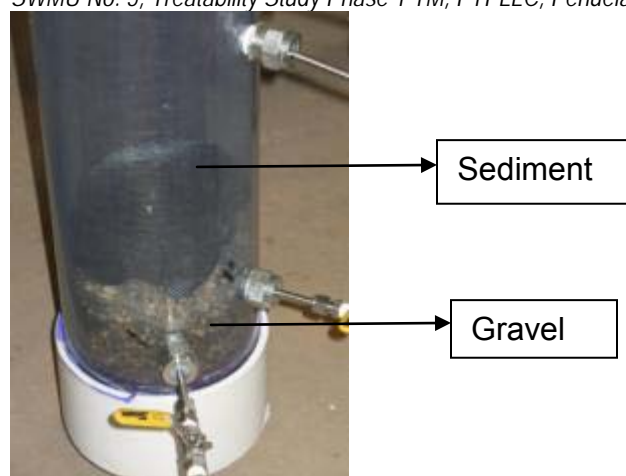
**Figure 5-4** presents experimental setup.

FIGURE 5-4  
Column Experiments Setup  
SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico



Each column consisted of a gravel base, a sediment layer, remedial cap layer, and clean sand layer with overlying water column. The gravel base was used at the bottom of each column to provide a uniformly distributed flow through the entire column (**Figure 5-5**). The gravel base layer consisted of graded gravel material with a woven 40-mesh geotextile fabric placed at the top to provide a finite boundary between the gravel and sediment.

FIGURE 5-5  
Gravel Base for Uniform Flow in the Column  
SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico



The sediments from core sample CS-1 was transferred to the sand cap column, CS-2 was transferred to CETCO Reactive Core Mat™ column, and CS-3 was transferred to the AquaBlok cap column with minimal disturbance to the sediment cores.

## Cap Layers

**CETCO Reactive Core Mat™:** The CETCO Reactive Core Mat™ was cut to the size of inner diameter of the column. Because of the high porosity of Reactive Core Mat™ relative to the surrounding media, no short circuiting was expected. The cross-section of the Reactive Core Mat™ used in the column contained 72 grams of organoclay material.

**AquaBlok Cap:** The reactive layer of AquaBlok cap was constructed using 1-inch-thick layer of ET-1 organoclay provided by AquaBlok. This layer was placed above geotextile used for a finite boundary for sediments and reactive layer. The 1-inch-thick layer of ET-1 organoclay contained 187 grams of organoclay material. Because of the impermeable nature of impervious AquaBlok material (3070 SW), only the reactive layer of the AquaBlok cap was evaluated in the laboratory. To create the similar physical conditions (weight) as an AquaBlok layer, a 4-inch-thick layer of inert 2-cm\_diameter glass beads was placed above the organoclay layer.

**Sand Cap:** A 24-inch-thick sand layer was placed above the sediment layer, separated by a geotextile.

## Sampling Ports

Sampling ports were constructed with stainless steel cord grips and stainless steel tubing with steel ball valve (**Figure 5-6**). Four sampling ports were inserted into each column: one into the gravel layer, one into the sediment layer, one into the sand layer, and one into the effluent layer. Samples from the gravel layer provided influent concentrations, samples from the sediment and sand layers provided concentrations before and after treatment, and samples from the effluent section above the sand layer provided final concentrations in the system.

FIGURE 5-6

Sampling Ports

*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*



## Pore Water Analysis

The pore water obtained from the sampling ports was collected in 2 mL amber Gas Chromatography (GC) vials containing 25 cm of 200/300 micron ( $\mu\text{m}$ ) Polydimethylsiloxane (PDMS) SPME fibers and equilibrated for 14 days at room temperature. SPME fibers were dried after equilibration time and immersed into 400  $\mu\text{L}$  of acetonitrile in another GC vial equipped with a 400  $\mu\text{L}$  glass insert followed by High Performance Liquid Chromatography (HPLC)



analysis. Experimental and analytical details are provided in the capping studies report (Gardner et al., 2010).

### 5.1.4 Column Sampling

#### Objective

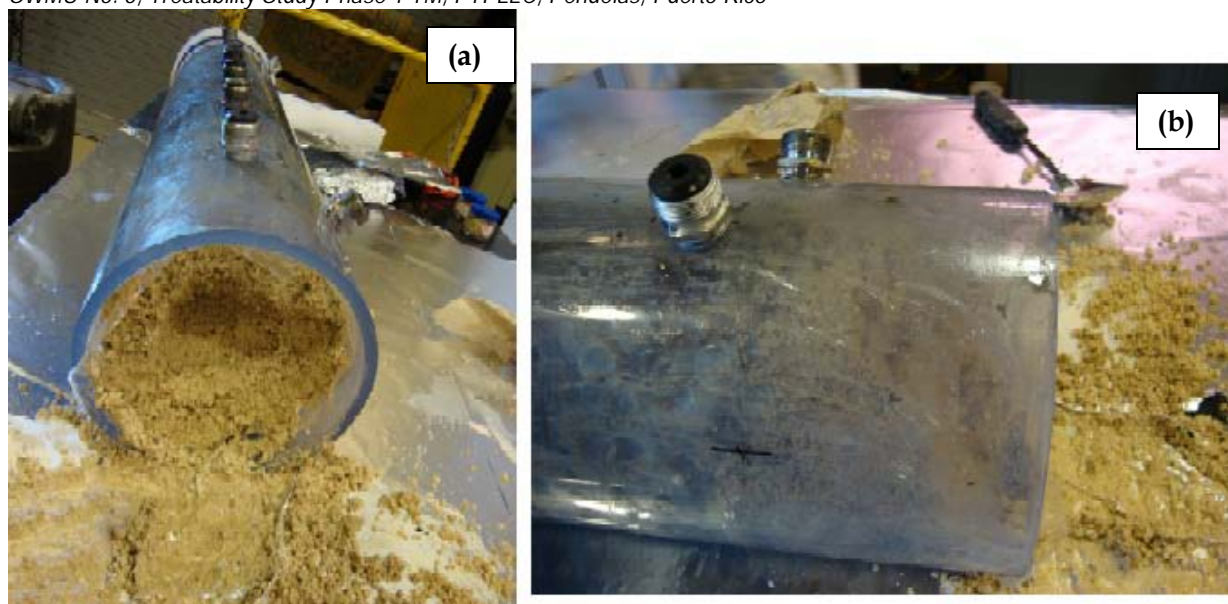
The objective of this study was to investigate the solid phase associated PAH concentrations in the sediments and the capping materials.

#### Method

At completion of the column studies after 5 weeks, material samples were recovered from the columns (**Figure 5-7**). Columns were drained and freeze-dried prior to the sampling. Samples from sand and sediment layers were recovered to determine PAH concentrations associated with the solid phase and experiments were completed.

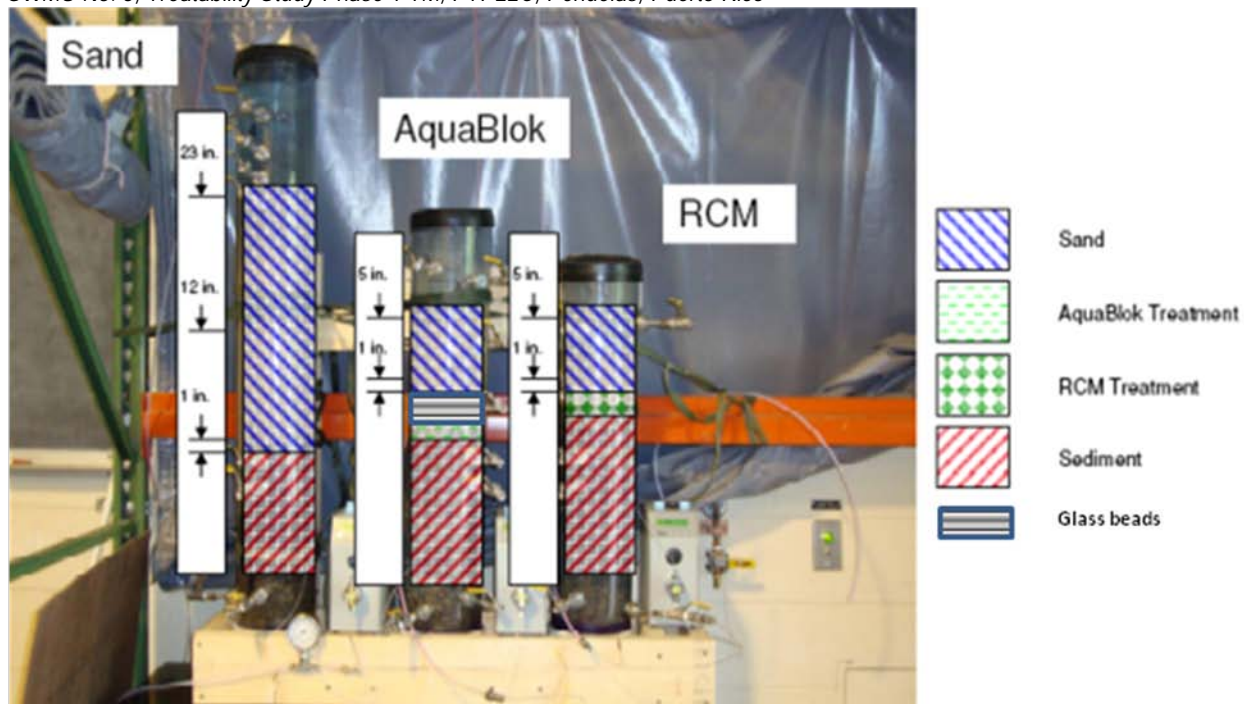
FIGURE 5-7

Top (a) and Bottom (b) Sand Sampling Locations – AquaBlok Column  
*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*



Samples were retrieved from the center of the sediment core and from two locations within the sand layer of Reactive Core Mat™ and AquaBlok cap columns 1 inch above the sand/treatment layer interface and 1 inch below the sand/water interface. For the sand cap, one additional sample was retrieved from the middle of the sand column. **Figure 5-8** shows the column sampling locations. The results of this study are provided in Section 6.

FIGURE 5-8  
Locations of Column Samples  
*SWMU No. 5, Treatability Study Phase 1 TM, PTP LLC, Peñuelas, Puerto Rico*



### 5.1.5 Gas Ebullition Testing

#### Objective

Sediments with high organic matter content produce gas bubbles that are hydrophobic and tend to accumulate organic contaminants and colloids from pore water. Gas bubbles can release contaminants from sediment-water interface into overlying water column or transport contaminants through caps. Gas bubbles can also affect the stability of impermeable or low-permeability caps.

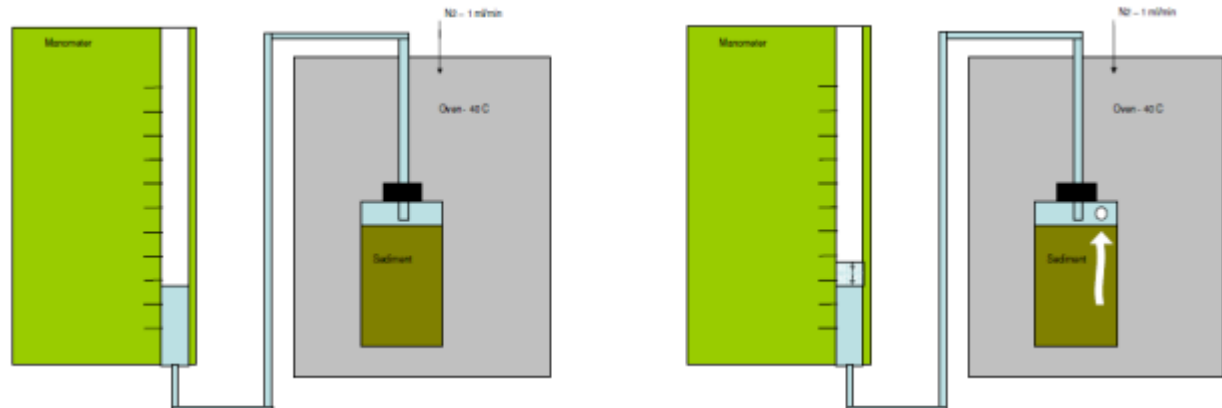
#### Experimental Setup

Gas generation was calculated by measuring the displacement of water within a 250 mL glass bottle. This was accomplished by placing 200 grams (200 mL) of sediment in a 250 mL rigid walled glass bottle. The remaining head space was filled with deionized water previously purged with ultra high purity (UHP) nitrogen for a 1-hour period. The prepared bottles were allowed to settle for 24 hours in a nitrogen-filled oven compartment at 20°C. The following day, the water level was returned to its original level at the top of the bottles and the bottles were capped with a septum screw cap. A 0.25-inch polyethylene rigid tube filled with deionized water was then punctured through the septum cap and run outside the oven to a manometer at a fixed height. The oven was set and activated to 40°C and the samples were then monitored for 2 weeks. Gas generation was measured by changes in water level on the manometer tubes as gas was generated within the sediment. **Figures 5-9 and 5-10** show the gas ebullition testing setup.

**FIGURE 5-9**  
 Gas Ebullition Testing Setup  
*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*



**FIGURE 5-10**  
 Conceptual Diagram of Experimental Design  
*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*





### 5.1.6 Cap Life Estimation Models

A Microsoft® Excel spreadsheet-based cap model was used to evaluate the ability of reactive materials to sequester PAHs from pore water at site conditions. The model inputs included pore water PAH concentrations and upwelling velocity. The contaminated sediment bed was assumed to be an infinite source of PAHs emanating from pore water into the reactive cap. The model assumes that diffusive flux does not contribute significantly to the total contaminant mass flux based on the Peclet number evaluation for column experiments.

$$P = \frac{v_x d}{D}$$

Where:

$D$  = diffusion coefficient

$v_x$  = velocity

$d$  = grain size diameter in the column

$P$  = Peclet number

$P < 0.02$ , dispersion dominated by diffusion

$P > 5$ , dominated by advective dispersion

By using the typical values for diffusion coefficient ( $5 \times 10^{-6}$  square centimeters per second [ $\text{cm}^2/\text{sec}$ ]), grain size for fine sand ( $d = 0.05$  mm) and upflow velocity of 2.8 centimeters per day ( $\text{cm}/\text{d}$ ), the Peclet number was calculated to be 0.03. This value represents transition between the two processes.

The model was developed considering advective mass flux of contaminants with a typical one-dimensional flow field. The calculated mass flux rates emanating from the sediments were assumed to be captured by the cap, which gives adsorbed concentrations over time. These adsorbed concentrations were used to calculate the aqueous concentrations in equilibrium with the sorbed phase. Mass released through the cap was calculated for the time step. Results are presented in Section 6.

## 5.2 Geotechnical Testing

### 5.2.1 Purpose

Bench scale geotechnical tests were performed to determine standard physical and engineering properties of the sediment, including:

- The internal friction angle, unconfined compressive strength, and specific gravity of the sediment
- Standard consolidation and simplified seepage consolidation properties

Simplified seepage consolidation tests and standard consolidation tests were performed to determine compressibility characteristics. Finite element modeling (FEM) was performed to obtain consolidation rate and vertical displacements of the cap.

### 5.2.2 Scope

The two 3-inch-diameter by 12-inch-long intact sediment cores referenced as GT-1 and GT-2 were used for geotechnical testing (**Figure 5-11**).

**FIGURE 5-11**  
Sediment Samples for Geotechnical Testing  
*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*



### 5.2.3 Sample Description

The first 35 mm of GT-1 (bottom of the sample) were used for water content measurement because the presence of wood chips, clumps, and rocks prevented the use of this material for geotechnical tests. The sediment had a strong odor similar to that of gasoline, and had voids ranging from 1 to 5 mm in diameter, filled with black and orange liquid. **Figure 5-12** shows a close-up view of the bottom of sample GT-1. The sediment was very soft, easily squished between the fingers with minor force, and the individual grains could not be distinguished by eye (Melton et al., 2009).

The sediment generally was very moist. The majority of the sample (nearly 90 percent) was dark grey, and showed some instances of sloped layering with roughly 1-mm-thick intercalations of light grey and dark grey material. **Figure 5-13** shows one of the samples after testing, with this layering visible on the top of the sample (Melton et al., 2009).

**FIGURE 5-12**  
Bottom of Sample GT-1 with Free Product  
*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*



FIGURE 5-13

Layering of Sample GT-1

*SWMU No. 5, Treatability Study Phase 1 TM, PTP LLC, Peñuelas, Puerto Rico*



## 5.2.4 Test Procedures

The following tests were conducted on specimens from these cores:

- Specific gravity (volumetric approach)
- Unconfined compressive strength (American Society for Testing and Materials [ASTM] D2166-06)
- Direct shear test (ASTM D3080-04)
- Standard consolidation (ASTM D2435-04)
- Simplified seepage consolidation (Shreedharan and Prakash, 1999)
- Finite Element Modeling using GEOSTUDIO™

The volumetric approach uses the displacement of water by a weighed mass in a known volume. The specific gravity is the resulting ratio of weight over volume.

The unconfined compressive strength test compresses a cylindrical sample under undrained conditions in a triaxial shear test device without confinement of the sample. The results allow the computation of the undrained shear strength of the sample.

The direct shear test applies a horizontal stress between two halves of a mold holding the specimen under a vertical confining pressure. Three vertical confining pressures are used (one on each of three specimens) to develop a relationship between vertical confining pressure and maximum shear stress.

The consolidation test applies a vertical load to a cylindrical specimen that is laterally confined. The loads are applied in steps to allow drainage of the specimen as it compresses.

The simplified seepage consolidation test applies a hydraulic gradient as the load and measures the compression daily until the sample reaches a constant volume. The steps are then repeated for greater values of hydraulic gradient, and the consolidation properties of the sediment are established using Terzaghi's theory. A permeability test is carried out at the end of the load step.

Test details and results are provided in the Consolidation and FEM Report (Melton et al., 2009). Selected results of these tests are presented in Section 6 of this Phase I report.

The geotechnical suite GEOSTUDIO™ was used for the numerical simulations of consolidation of the sediment under the various cap loadings. The code uses the Modified Cam-Clay constitutive model to simulate the stress-strain behavior of soft sediments. Input parameters are obtained from consolidation tests and the internal friction angle of the sediment, and the FEM models are used to estimate the consolidation rate and magnitude of settlements expected on the sediment surface as a result of deployment of the cap.

The sediment profile was developed to account for the decrease in void ratio during consolidation due to the increased effective stress. Three horizontal layers of sediment were defined with equal values of void ratio and consolidation parameters and the unit weight of the sediment was modified with depth to reflect the change of void ratio due to increased effective stress. Detailed input parameters, model layer properties, and results of the FEM model are presented in Section 6.

## SECTION 6

# Results and Discussion

## 6.1 Sediment

### 6.1.1 Geotechnical Tests

#### Cone Penetrometer Testing

**Table 6-1** presents the CPT field parameters. All six probes encountered refusal at depths of 17.6 to 42 feet sediment thickness. Probe 2 refused at a shallow depth of 5 feet (obstruction); the rig was moved several feet laterally and Probe 2A was performed. **Figure 2-1** shows probe locations.

TABLE 6-1  
Geotechnical Properties of Sediments  
*Phase 1 Technical Memorandum, PTPLLC SWMU No. 5*

Date	Samples	Barge deck height above water surface (ft)	Water depth to sediment (ft)	Sediment (ft)		Total Depth (ft)
5/18/2009	HILLCPT1	2.5	5	17.6	Refusal	18
5/18/2009	HILLCPT2	2.5	8.5	5	Refusal	5
5/18/2009	HILLCPT2A	2.5	8.5	11	Refusal	11
5/18/2009	HILLCPT3	2.5	4.5	31	Refusal	31
5/19/2009	HILLCPT4	2.5	11.5	33	Refusal	33
5/19/2009	HILLCPT5	2.5	5.5	42	Refusal	42

Notes:  
ft - feet

The CPT data indicate predominantly soft, fine-grained silts and organic materials with occasional lenses of high resistance, and generally increasing resistance with depth. At refusal depth, the increase in resistance is typically sudden, suggesting a soft overburden overlying rock. CPT logs of these probes are presented in **Appendix D**.

#### Classification Testing

Sediment and sand samples were shipped to Kemron Environmental Services for classification testing. Four undisturbed sediment samples were classified via Atterberg Limits to be highly plastic organic silt with high liquid limits (57 to 107) and high plastic limits (34 to 56). The moisture content data indicate that the silt should be considered a liquid for soil classification purposes. The LOI test results indicate an organic content of approximately 10 percent, which is not considered to be highly organic. The classification data for the sediments are summarized in **Table 6-2**.

TABLE 6-2  
Soil Classification Properties of Sediments  
Phase 1 Technical Memorandum, PTPLLC SWMU No. 5

Sample ID	Sample Type	Moisture Content (%)	Atterberg Limits			Loss on Ignition (organic content) (%)
			Liquid Limit	Plastic Limit	Plasticity Index	
05-SCU1	Sediment	117.69	57	34	23	9.1
05-SCU2	Sediment	172.08	75	35	40	9.7
05-SCU3	Sediment	228.33	107	56	51	9.5
05-SCU4	Sediment	186.89	77	45	32	11.1

Three sand samples proposed for use as cap material were tested for classification and found to be non-plastic poorly graded sand with silt. This material typically consists of 4 percent gravel, 85 percent sand, 6 percent silt, and 5 percent clay. Particle size distribution data and graphs are available in project records. **Table 6-3** summarizes classification data for the sand.

TABLE 6-3  
Soil Classification and Particle Size Analysis of Sand  
Phase 1 Technical Memorandum, PTPLLC SWMU No. 5

Sample Id	Sample Type	Soil Classification		Particle Size Analysis			
		USCS	AASHTO	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
05-SS1	Sand	SP-SM	A-2-4	3.3	85.2	6.1	5.4
05-SS2	Sand	SP-SM	A-2-4	4.0	84.8	5.8	5.4
05-SS3	Sand	SP-SM	A-2-4	2.6	85.9	6.1	5.4

Notes:  
AASHTO - American Association of State Highway and Transportation Officials  
USCS – Uniform Soil Classification System  
SP - poorly graded sand  
SM - silty sand  
Canarico Quarry, San Juana Diaz, PR

These sediment and sand samples were not tested for engineering properties; further tests were run on similar samples by the University of New Hampshire, as described in the following subsection.

## Engineering Properties

Two undisturbed sediment samples were tested for engineering properties at the University of New Hampshire geotechnical laboratory in conjunction with the column studies. Sample GT-1 contained wood chips, clumps, and rocks, and was used for classification tests only. The sample had a strong odor similar to that of gasoline, with black and orange liquids in 1 to 5 mm voids.

The following properties were determined from the geotechnical tests on samples GT-1 and GT-2:

- Specific gravity of the sediment particles ( $G_s = 2.436$ , typical when organic matter is present)
- Unconfined compressive strength (triaxial test): sample collapsed during preparation
- Undrained shear strength by Torvane tests ( $S_u = 0.98$  to  $1.57$  kilopascal (kPa) [ $20.48$  to  $32.77$  lb/ft<sup>2</sup>])
- Sample was too soft for pocket penetrometer test
- Effective angle of friction by direct shear test ( $\phi' = 38^\circ$ )
- Consolidation index ( $C_c = 0.9769$ )
- Recompression index ( $C_r = 0.043$ )
- Permeability ( $10^{-5}$  to  $10^{-9}$  cm/sec (effective stresses of  $20$  to  $2,000$  kPa))

Further details and graphic representations of the consolidation test results are presented in the University of New Hampshire report (Melton, 2009).

The test results showed an important decrease in void ratio and permeability during consolidation. Thus, a sediment profile of four layers was defined from the test results as input to the FEM model. These layers included three layers of sediment at increasing effective stress, and one layer of sand.

The sediment profile at Station 6+00 is comprised of 10 to 12 feet of clay (CL) over a 0.5 to 1 foot layer of silty sand (SM). The properties of the sand layer were assumed to be those of conventional sand. **Table 6-4** summarizes the geotechnical parameters used in the FEM simulation for all layers.

TABLE 6-4  
Summary of Geotechnical Parameters for FEM  
Phase 1 Technical Memorandum, PTPLLC SWMU No. 5

Depth [ft]	Description	e	Gs	$\gamma$ [pcf]	Cc	Cr	E [psf]	$\phi'$ [°]
0 – 1.19	Clay (CL)	4.5	2.436	78.69	0.9769	0.043	-	38
1.19 – 3.56	Clay (CL)	4	2.436	80.32	0.9769	0.043	-	38
3.56 – 12	Clay (CL)	3.5	2.436	82.31	0.9769	0.043	-	38
12 – 13	Silty sand (SM)	1	-	115	-	-	210,000	30

Notes:

E = void ratio

Gs = specific gravity of solids

$\gamma$  = unit weight

E = modulus of elasticity

Cap materials were weighed and simulated as a uniform vertical load as follows:

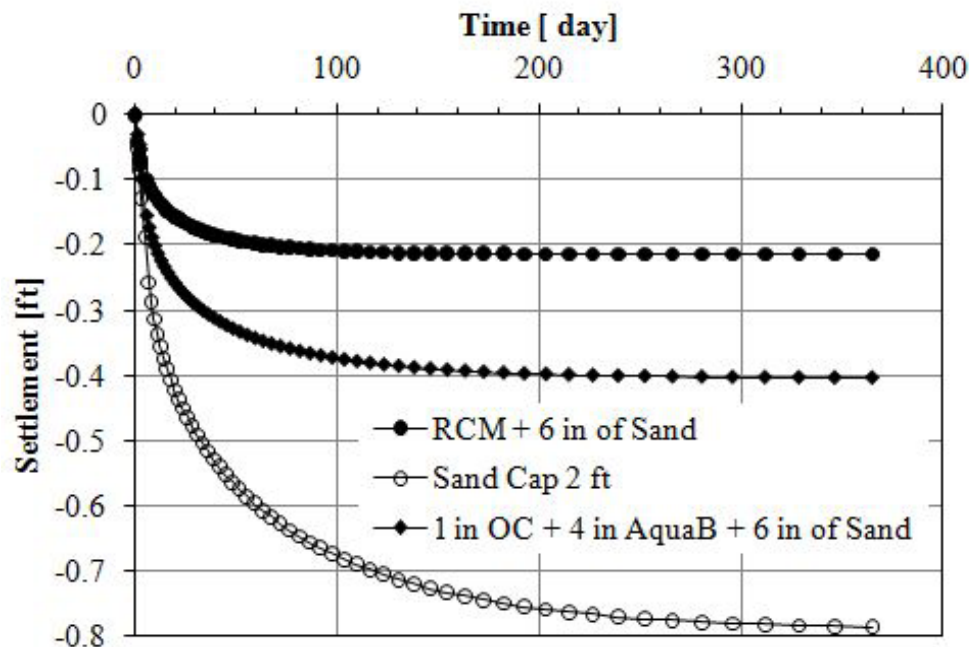
1. CETCO Reactive Core Mat™ plus 6 inches of sand on top.
2. Organoclay (1 inch) plus Aquablok™ (4 inches), plus 6 inches of sand on top
3. Sand-only cap, 2 feet thick

Settlements resulting from sediment consolidation after placement of caps are caused by dissipation of excess pore pressure over time, as presented in **Figure 6-1**.

FIGURE 6-1

Cap Settlement with Sediment Consolidation over Time

SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico



## 6.1.2 Analytical

Sediment samples were collected from the proposed pilot cap test and backfill areas and were analyzed by Lancaster Laboratories for PAHs and general chemistry. Sediment samples were analyzed to evaluate the concentrations of PAHs in test areas and to assist in development of a remedial alternative that prevents unacceptable levels of ecological exposure to SVOC-contaminated sediments in the canal. The PAH concentrations in sediments are presented in Table 6-5.

Table 6-5

PAH concentrations in Sediments

Treatability Study Phase I Technical Memorandum, PTPLLC SWMU No. 5

PAH	Marine Sediment Ecological Screening Values (ESVs)		Equilibrium Partitioning-Based Sediment Values (ESVs) **	05-SCD1	05-SCD1-ELU	05-SCD2	05-SCD3	05-SCD4	05-SCD5	05-SCD6	05-SCD7
	ug/kg	Type*	ug/kg	ug/kg	ug/L	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
Acenaphthene	16.0	ER-L	5,335	30,000 =	45 =	7,700 =	38,000 =	27,000 =	22,000 =	62,000 =	27,000 =
Acenaphthylene	44.0	ER-L	3,201	63,000 =	78 =	25,000 =	67,000 =	56,000 =	70,000 =	130,000 =	61,000 =
Anthracene	85.3	ER-L	10,670	28,000 =	5 =	9,300 =	33,000 =	22,000 =	28,000 =	48,000 =	26,000 =
Benzo(a)anthracene	261	ER-L	5,335	16,000 =	1 U	12,000 =	27,000 =	20,000 =	33,000 =	26,000 =	28,000 =
Benzo(a)pyrene	430	ER-L	4,802	9,000 J	1 U	9,100 =	18,000 =	13,000 =	23,000 =	15,000 =	18,000 =
Benzo(b)fluoranthene	1,800	AET	11,155	7,600 J	1 U	7,400 =	14,000 =	11,000 =	18,000 =	12,000 =	15,000 =
Benzo(g,h,i)perylene	670	AET	1,504	2,800 =	1 U	2,600 =	5,500 =	3,800 =	6,500 =	4,300 =	6,000 =
Benzo(k)fluoranthene	1,800	AET	11,155	3,000 =	1 U	2,600 =	4,700 =	4,000 =	7,500 =	4,300 =	6,100 =
Chrysene	384	ER-L	5,335	15,000 J	1 U	12,000 =	28,000 =	19,000 =	32,000 =	25,000 =	27,000 =
Dibenz(a,h)anthracene	63.4	ER-L	582	1,300 =	1 U	1,100 =	2,400 =	1,700 =	2,500 =	2,100 =	2,200 =
Fluoranthene	600	ER-L	6,790	26,000 =	3 J	16,000 =	42,000 =	29,000 =	43,000 =	49,000 =	35,000 =
Fluorene	19.0	ER-L	1,116	41,000 =	47 J	5,900 =	12,000 =	48,000 =	19,000 =	160,000 =	21,000 =
Indeno(1,2,3-c,d)pyrene	600	AET	1,649	2,400 =	1 U	2,200 =	4,600 =	3,200 =	5,700 =	3,800 =	5,400 =
Naphthalene	160	ER-L	4,802	21,000 =	73 =	620 =	1,200 =	160,000 =	7,000 =	230,000 =	22,000 =
Phenanthrene	240	ER-L	5,335	120,000 =	56 =	21,000 =	130,000 =	130,000 =	73,000 =	350,000 =	69,000 =
Pyrene	665	ER-L	48,500	45,000 =	5 =	38,000 =	78,000 =	60,000 =	94,000 =	81,000 =	78,000 =

\* AET: Apparent Effect Threshold and ER-L: Effects Range-Low

\*\* See Table 6-6



The detected PAH concentrations in sediments were compared to ecological screening values (ESVs) for protection of benthic invertebrates, in order to evaluate potential risk to benthic communities. ESVs used in this evaluation were based upon two approaches, including the Screening Level Concentration (SLC) approach and the Equilibrium Partitioning (EqP) approach. Generally, SLC-based sediment ESVs are used to conduct the initial sediment screening, and EqP-based ESVs are used to estimate chemical bioavailability based on site specific measure of total organic carbon (TOC).

The SLC approach relies on studies that correlate chemical concentrations in sediment with some measure of benthic community impairment. These ESVs do not consider site-specific bioavailability, and correlate effects to each individual chemical without accounting for the possible effects that might be produced by other chemicals present in the sediment samples used to develop the value. ESVs for marine sediment were identified via a hierarchical process. The order of preferred ESV sources (first choice to last choice) is presented below. Selected ESVs identified using this stepwise process are provided in Table 6-5.

- Effects range-low (ER-L) values (Long et al., 1995).
- EcoTox thresholds (USEPA, 1996a).
- Numerical sediment quality assessment guidelines for Florida coastal waters (MacDonald et al., 1994).
- Canadian sediment quality guidelines for the protection of aquatic life (CCME, 2002).
- NOAA SQiRTs (Buchman, 2008) for other values not included in the above-listed sources.

EqP, which incorporates a measure of sediment chemical bioavailability, is appropriate for developing sediment effect levels for non-ionic (non-polar) organic chemicals (USEPA, 1993; 1996a). EqP theory holds that a non-ionic chemical present in sediment partitions between sediment organic carbon, interstitial (pore) water, and benthic organisms. For these types of chemicals, it has been demonstrated that biological effects are correlated not to the total concentration of a chemical in bulk sediment but to the pore water concentration. Thus, effect levels based on water-only exposures (such as AWQC values) can be used to estimate potential biological effects from sediment exposures when coupled with a measure of the ratio of the concentration in pore water to the concentration in sediment organic carbon (the organic carbon partition coefficient,  $K_{oc}$ ) using the following formula (USEPA, 1996a; 1999):

$$EqPValue = (f_{oc}) (K_{oc}) (FCV)$$

where:	EqPValue	=	Equilibrium partitioning-based value (µg/kg)
	$f_{oc}$	=	Total organic carbon content (percent, as a fraction)
	$K_{oc}$	=	Normalized adsorption (partition) coefficient (L/kg)
	FCV	=	Chronic AWQC or its equivalent (µg/L)

The sorption capacity of the sediment is determined by the mass fraction of organic carbon present in the sediment ( $f_{oc}$ ). For sediments with a  $f_{oc} > 0.2$  percent by weight, the organic carbon appears to be the predominant determinant for chemical sorption. Thus, the amount of organic carbon present in the sediment controls the bioavailability of a non-ionic chemical through

sorption. In general, the higher the organic carbon content of the sediment, the lower the bioavailability of the chemical.

EqP values identified in the literature (calculated as described above) are presented in **Table 6-6**. These values were originally based on 1 percent TOC, and are normalized to site mean TOC (4.85 percent; see Table 6-7) by multiplying the EqP by 4.85 percent.

**TABLE 6-6**  
Marine Sediment Values Based on Equilibrium Partitioning (EqP)  
*Phase 1 Technical Memorandum, PTPLLC SWMU No. 5*

Chemical	EqP-Based Value (ug/kg)	Units	Reference	Site Mean TOC (%)	Normalized EqP-Based Value (ug/kg)
Acenaphthene	1,100	ug/kg	USEPA 1996a	4.85	5,335
Acenaphthylene	660	ug/kg	Washington State 1995	4.85	3,201
Anthracene	2,200	ug/kg	Washington State 1995	4.85	10,670
Benzo(a)anthracene	1,100	ug/kg	Washington State 1995	4.85	5,335
Benzo(a)pyrene	990	ug/kg	Washington State 1995	4.85	4,802
Benzo(b)fluoranthene	2,300	ug/kg	Washington State 1995	4.85	11,155
Benzo(g,h,i)perylene	310	ug/kg	Washington State 1995	4.85	1,504
Benzo(k)fluoranthene	2,300	ug/kg	Washington State 1995	4.85	11,155
Chrysene	1,100	ug/kg	Washington State 1995	4.85	5,335
Dibenz(a,h)anthracene	120	ug/kg	Washington State 1995	4.85	582
Fluoranthene	1,400	ug/kg	USEPA 1996a	4.85	6,790
Fluorene	230	ug/kg	Washington State 1995	4.85	1,116
Indeno(1,2,3-cd)pyrene	340	ug/kg	Washington State 1995	4.85	1,649
Naphthalene	990	ug/kg	Washington State 1995	4.85	4,802
Phenanthrene	1,100	ug/kg	USEPA 1996a	4.85	5,335
Pyrene	10,000	ug/kg	Washington State 1995	4.85	48,500

The results for sediments general chemistry including moisture content and total organic carbon (TOC) that were analyzed by Lancaster Laboratories are presented in **Table 6-7**.

**TABLE 6-7**  
Sediments General Chemistry  
*Phase I Technical Memorandum, UCCLLC SWMU No. 5*

Sample ID	Date	% Moisture		TOC (mg/kg)	
05-SCD1	5/16/2009	56.3	=	70,300	=
05-SCD2	5/16/2009	67.1	=	48,700	=
05-SCD3	5/16/2009	61.3	=	43,400	=
05-SCD4	5/16/2009	71.3	=	37,700	=
05-SCD5	5/16/2009	63.4	=	31,900	=
05-SCD6	5/16/2009	71.3	=	76,300	=
05-SCD7	5/16/2009	64.3	=	31,400	=
Mean =		65.0		48,529	

## 6.2 Pore Water

During Phase 1 activity, pore water sampling was conducted in the proposed pilot scale capping study areas between transects T-2+00 and T-8+00, toward the northern part of the CWC. Pore water was collected and tested at Lancaster Laboratories for PAH concentrations to evaluate the concentration and mobility of dissolved contaminants in the surface/groundwater system and capping/backfill system. These samples were also analyzed for alkalinity and TOC. Some of the samples were also analyzed for metals. These samples were analyzed in two ways one prior to centrifugation and one after centrifugation to determine if there is any need for additional filtration once the pore water samples are collected using pushpoint samplers.

Pore water sampling results are presented in **Tables 6-8, 6-9** and **6-10**. The concentrations of PAHs and metals were compared to surface water ESVs. ESVs for marine surface water were identified via a hierarchical process. The order of preferred ESV sources (first choice to last choice) is presented below. Selected ESVs identified using this stepwise process are provided in Table 6-8.

Marine/estuarine ESV sources are as follows:

Puerto Rico water quality standards (PREQB, 2003) for aquatic life (human health-based values are not considered).

NAWQC (USEPA, 2009; USEPA, 2006a).

EcoTox thresholds (USEPA, 1996a).

NOAA SQuiRTs (Buchman, 2008) for other values not included in the above-listed sources (New Zealand-based values from this source were not used).

Other relevant studies or sources from the literature for multiple chemical groups (e.g., EPA Region III BTAG marine screening benchmarks (USEPA, 2006b).

Marine chronic surface water screening values for PAHs are very limited, and were only available for four PAHs. Additional values were identified for anthracene and pyrene in EPA Region III BTAG (USEPA, 2006b), but were found to be derived chronic values based on acute toxicity tests conducted in-house by the Texas Commission on Environmental Quality, and therefore have a significant degree of uncertainty that is not appropriate for this assessment.

Table 6-8 presents the concentrations of PAHs in pore water. There were three pore water samples, 05-PW3C, 05-PW7C and 05-PW11C, that were centrifuged in lab prior to PAH analysis. PAH concentrations in these samples were compared to the samples that were collected from the same location and were not centrifuged prior to the analysis (05-PW3, 05-PW-7 and 05-PW11 respectively) in order to determine the requirement of filtering pore water samples prior to the analysis to avoid any interference that can be caused by colloids or any natural organic matter present in the samples.

TABLE 6-8  
PAH Concentrations in Pore Water  
Phase I Technical Memorandum, UCCLLC SWMU No. 5

PAH	Marine Surface Water Ecological Screening Values (ESVs)		05-PW1	05-PW3	05-PW3C	05-PW4	05-PW5	05-PW7	05-PW7C	05-PW8	05-PW9	05-PW10	05-PW11	05-PW11C	05-PW12	05-PW13	05-PW14
			5/21/09	5/21/09	5/21/09	5/21/09	5/20/09	5/20/09	5/20/09	5/20/09	5/20/09	5/20/09	5/20/09	5/20/09	5/20/09	5/20/09	5/20/09
	(ug/L)	Source	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
1-methylnaphthalene	-	-	1 UJ	1 U	1 U	1400	= 14	= 84	= 4 J	20	= 1 J	16	J	1 U	1 U	2 J	1 U
2-Methylnaphthalene	-	-	1 UJ	1 U	1 U	1800	= 2 J	22	= 1 U	3	J	1 U	1 J	1 U	1 U	1 U	1 U
Acenaphthene	40	USEPA, 1996a; FCV	5 J	2 J	1 J	220	= 12	= 38	= 8	3	J	2 J	2 J	1 U	1 U	1 J	1 U
Acenaphthylene	-	-	6 J	5	= 2 J	470	= 17	= 57	= 12	7	= 7	= 6	= 2 J	2 J	3 J	2 J	1 J
Anthracene	-	-	1 J	1 J	1 U	140	= 5	= 26	= 2 J	1 U	2 J	1 U	1 U	1 U	1 U	1 U	1 U
Benzo(a)anthracene	-	-	1 U	1 J	1 U	78	= 3 J	10	= 1 U	1 U	2 J	1 U	1 U	1 U	1 U	1 U	1 U
Benzo(a)pyrene	-	-	1 U	1 J	1 U	47	= 1 J	6	= 1 U	1 U	1 J	1 U	1 U	1 U	1 U	1 U	1 U
Benzo(b)fluoranthene	-	-	1 U	1 J	1 U	35	= 1 J	4	J	1 U	1 U	1 J	1 U	1 U	1 U	1 U	1 U
Benzo(g,h,i)perylene	-	-	1 U	1 U	1 U	13	= 1 U	2	J	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Benzo(k)fluoranthene	-	-	1 U	1 U	1 U	13	= 1 U	1	J	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Chrysene	-	-	1 UJ	2 J	1 U	77	= 3 J	11	= 1 U	1 U	2 J	1 U	1 U	1 U	1 U	1 U	1 U
Dibenz(a,h)anthracene	-	-	1 U	1 U	1 U	5	J	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Fluoranthene	11.0	USEPA, 1996a; FCV	2 J	2 J	1 U	170	= 8	= 24	= 2 J	1 U	3 J	1 U	1 U	1 U	1 U	1 U	1 U
Fluorene	-	-	1 J	1 J	1 U	600	= 27	= 110	= 15	4	J	2 J	4 J	1 U	1 U	2 J	1 U
Indeno(1,2,3-c,d)pyrene	-	-	1 U	1 U	1 U	11	= 1 U	1	J	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Naphthalene	1.40	Buchman, 2008	1 UJ	1 U	1 U	6000	= 1 J	14	= 1 J	2	J	1 U	1 UJ	1 U	1 U	1 U	1 U
Phenanthrene	8.30	USEPA, 1996a; FCV	1 J	3 J	1 U	980	= 26	= 160	= 3 J	2	J	3 J	2 J	1 U	1 U	2 J	1 U
Pyrene	-	-	2 J	3 J	1 U	230	= 9	= 30	= 2 J	1 U	5 J	1 J	1 J	1 J	1 J	1 J	1 J

Notes:  
Boxed and bold values indicates detections  
FCV: Final Chronic Value

No difference was noticed in case of 05-PW11 and 05-PW11C but significant differences were noticed in case of 05-PW7 and 05-PW7C with some differences in case of 05-PW3 and 05-PW3C. The three unfiltered samples (05-PW3, 05-PW7 and 05-PW11) were also analyzed for presence of metals. The results for metal analysis are presented in **Table-6-9**.

**TABLE 6-9**  
Metal Concentrations in Pore Water  
*Phase I Technical Memorandum, UCCLLC SWMU No. 5*

Sample ID	Date	Result (ug/L)										
		Arsenic		Barium	Cadmium		Chromium, total		Lead		Mercury	
Marine Surface Water Ecological Screening Values (ESVs)	ug/L	1.4	WQS	200	8.85	AWQ C	50.4	AWQ C	8.52	AWQ C	0.051	WQS
05PW-03	5/21/2009	36	U	17.2 J	10	U	17	U	34.5	U	0.13	U
05PW-07	5/20/2009	10	U	28.8 =	2	U	33.1	J	6.9	U	0.26	U
05-PW11	5/20/2009	10	U	7.7 =	2	U	3	U	6.9	U	0.056	U

Notes:  
AWQC: Ambient Water Quality Criterion  
WQS: Water Quality

All the porewater samples collected in the field were analyzed for general chemistry and the results for alkalinity and TOC are presented in **Table 6-10**.

**TABLE 6-10**  
Pore Water General Chemistry  
*Treatability Study Phase 1 Technical Memorandum, PTPLLC SWMU No. 5*

Station ID	Date	Alkalinity to pH 4.5 (mg/L)		Alkalinity to pH 8.3 (mg/L)		TOC (mg/L)	
05PW-01	5/21/2009	182	=	0.46	U	1.9	J
05PW-03	5/21/2009	134	=	0.46	U	0.88	J
05PWC-03	5/21/2009	NM		NM		0.79	J
05PW-04	5/21/2009	839	=	0.46	U	13.2	=
05PW-05	5/20/2009	148	=	0.46	U	3.3	=
05PW-07	5/20/2009	279	=	0.46	U	3.3	=
05PWC-07	5/20/2009	NM		NM		5.1	=
05PW-08	5/20/2009	304	=	0.46	U	1.5	=
05PW-09	5/20/2009	280	=	0.46	U	3.5	=
05PW-10	5/20/2009	132	J	0.46	U	0.92	J
05-PW11	5/20/2009	118	=	0.46	U	0.5	U
05-PWC11	5/20/2009	NM		NM		0.5	U
05-PW12	5/20/2009	132	=	0.46	U	0.54	J
05-PW13	5/20/2009	132	=	0.46	U	0.5	U
05-PW14	5/20/2009	176	=	0.46	U	0.56	J

Notes:  
NM = Not measured



## 6.3 Gas Ebullition

Gas ebullition testing performed to evaluate gas generation resulting from sediment consolidation caused by cap placement showed no notable results. The sediments that were tested for gas generation capabilities were recovered 6 months prior to the experiments. These sediments were also used for column testing and had gone through temperature changes that might have exhausted the available energy resources affecting the gas generation capacity of the sediments. Gas ebullition may be more accurately evaluated in the field due to consolidation under a cap and organic decomposition.

## 6.4 Seepage Flux

Because great variability in seepage rates can occur over short distances, four meters were used at different locations for a wider characterization of surface water - groundwater exchange. The flux rates obtained at the site varied from  $10^{-7}$  cm/sec to  $10^{-6}$  cm/sec. Seepage meters are not practical devices for measuring flow across very fine-grained sediments with low hydraulic conductivities (less than  $10^{-7}$  cm/sec) or under very low vertical gradients and low flow rates. These results suggest low flux rates at the site, and could be due to fine-grained sediments, low gradients, or both. These Phase 1 results are considered preliminary at this time because the meters were deployed for relatively short periods of time and measured small changes in water volume.

The large changes in measured seepage over very short distances may result from a combination of various factors such as

- Sediment hydraulic conductivity
- Vertical hydraulic gradient
- Presence of preferential flow paths
- Clogging layers formed by entrapped air, gas, or organic matter
- Tidal fluctuations
- Depth to a lower confining unit or variations in saturated zone thickness due to bedrock

## 6.5 Surface Water and Groundwater Levels

Measurements from the transducers were downloaded and processed on a personal computer to provide time/depth data and charts. The draft charts of the water level versus time for the two wells and the canal showed daily tidal fluctuations for F-15 and the canal water, but periodic fluctuations in the D-22 data were barely perceptible. Some gradual lowering of average water levels was also indicated. Overall, the data are suspect and are not considered reliable because of unexplained rapid variations in recorded water levels and survey inconsistencies during the Phase 1 field work. Thus, additional measurements with improved survey data will be necessary to corroborate these data and provide reliable representations of groundwater-surface water influences.

## 6.6 Cap Material

### 6.6.1 Batch Experiments

Batch experiments were performed to estimate the adsorption capacities of CETCO organoclay PM-199, AquaBlok organoclay provided by Aqua Technologies as ET-1 organoclay, and sand. These experiments included kinetic and equilibrium studies.

The kinetic experiments were performed to estimate the rate of adsorption of PAHs onto cap materials. Results indicated that approximately 90 percent of PAHs adsorption for both types of organoclay occurred within 6 hours. Removal rate was slower for sand but most of the compounds for sand also achieved 90 percent adsorption in 6 hours. The details of experiments and kinetics plots are provided in the column studies report (Gardner et al., 2010).

The adsorption equilibrium studies were conducted to determine adsorption affinity of PAHs for cap materials. Results showed significant adsorption affinity of PAHs for both types of organoclay compared to that of sand. Due to significantly lower adsorption affinities, partition coefficients for sand could not be calculated. **Table 6-11** presents the linear partition coefficients for CETCO and AquaBlok organoclays.

TABLE 6-11  
Linear Partition Coefficients  
SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico

	CETCO Organoclay (L/kg)	AquaBlok Organoclay (L/kg)
Naphthalene	3.24E+03	1.13E+02
Acenaphthylene	6.23E+03	6.70E+02
Ace+2M-N+Fluor <sup>1</sup>	1.02E+05	1.28E+04
Phenanthrene	1.38E+05	1.47E+04
Anthracene <sup>2</sup>	>1.64E+04	2.17E+04
Fluoranthene	5.69E+04	5.66E+04
Pyrene	6.23E+04	3.03E+04
Benzo(a)anthracene <sup>2</sup>	>1.47E+05	>1.47E+05
Chrysene	2.47E+04	3.96E+04
Benzo(b)fluoranthene	2.31E+04	4.62E+04
Benzo(k)fluoranthene	1.26E+04	2.50E+04
Benzo(a)pyrene	7.28E+04	8.77E+04

<sup>1</sup> Compounds Acenaphthene, 2 Methylanthracene and Fluorene are combined and presented as one compound

<sup>2</sup> Equilibrium solution concentrations are below detection limit therefore no results are reported

This table is obtained from Capping studies report (Gardner et al., 2010).

CETCO organoclay was reported to have stronger affinity for the lighter PAH compounds (such as acenaphthylene, acenaphthene+2-methylnaphthalene+fluorene and phenanthrene) compared to AquaBlok organoclay. Both organoclays performed similarly for fluoranthene. Anthracene was reported below detection limit for CETCO organoclay. Benzo(a)anthracene was reported below detection limit for both CETCO and AquaBlok organoclays.

## 6.6.2 Column Experiments

The column experiments were performed to determine the effectiveness of three types of caps including CETCO Reactive Core Mat™ filled with PM-199 organoclay, AquaBlok reactive cap layer consisting of ET-1 organoclay, and sand. The column experiments were conducted with undisturbed sediment cores retrieved from the field and site water.

For baseline characterization of pore water present in the different layers of each column, pH, ORP, temperature, and dissolved oxygen were measured at multiple sampling periods. **Table 6-12** presents the average pH and temperature readings and upper and lower ORP ranges as observed. The average influent dissolved oxygen concentration was 4.98 mg/L and the average effluent dissolved oxygen concentration was 5.45 mg/L.

**TABLE 6-12**  
Baseline Pore Water Characteristics  
*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*

	Temperature (°C)	pH	ORP (mV)
Sand Column			
Influent	21.60	8.85	>22.7
Sand	21.55	8.65	<-12.1
Effluent	20.95	8.62	>79.4
AquaBlok Column			
Influent	21.75	8.69	>3.2
Sand	21.35	8.62	<-16.1
Effluent	21.85	8.57	>6.9
RCM Column			
Influent	21.15	8.08	>2.7
Sand	21.35	7.99	<-40.8
Effluent	21.50	8.21	>282.4

This table is obtained from Capping studies report (Gardner et al., 2010).

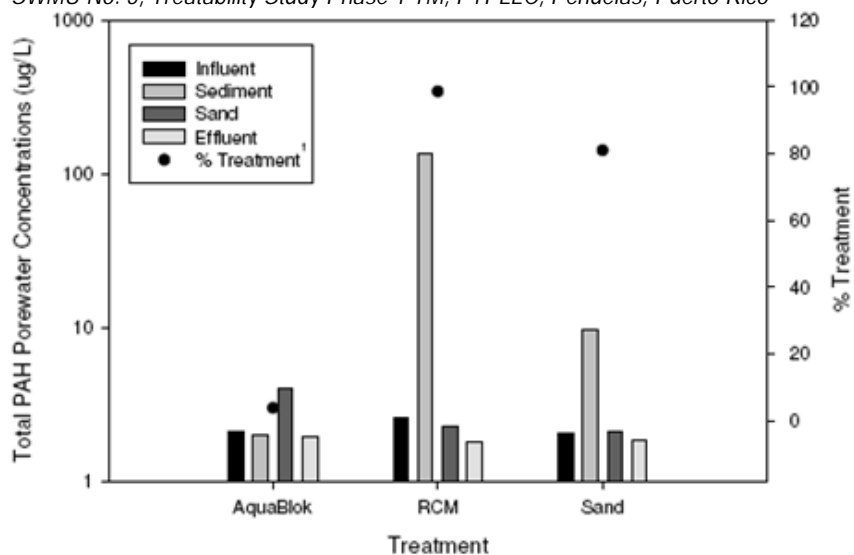
PAH concentrations in pore water for all media within the three columns were analyzed for up to a 55-day period. The details of experimental design and results are provided in the column studies report (Gardner et al., 2010).

The CETCO Reactive Core Mat™ column had the highest pore water PAH concentrations in the sediment and consistently showed high levels of treatment (**Figure 6-2**). In the CETCO Reactive Core Mat™ column, the sediment layer had PAH concentrations one to two orders of magnitude higher than those of the AquaBlok and sand columns. The PAH concentrations in the sand and effluent layers of the AquaBlok column were similar to those of the Reactive Core Mat™ column but the sediment pore water PAH concentrations were very low. **Figure 6-2** presents the pore water PAH concentrations in different layers of all three columns and percent treatment of all three types of caps.

FIGURE 6-2

Total PAH pore water concentrations and percent treatment

*SWMU No. 5, Treatability Study Phase 1 TM, PTP LLC, Peñuelas, Puerto Rico*



This significant and consistent variation in pore water PAH concentrations recovered from the sediment layer in all the three columns rendered the results ineffective in providing a comparison of the three treatment approaches.

### 6.6.3 Column Sampling

After completion of column studies, grab samples from sediment and sand layers were obtained from each column to investigate total content of solid-phase associated PAHs. Consistent variability in the pore water was observed during column experiments, with high total PAH concentrations in the Reactive Core Mat™ column sediment layer. However, this variability was not observed when the sediment samples from each column were analyzed for solid phase associated PAHs.

All sediments were similar in total PAH content with differences too small to account for the observed differences in pore water PAH concentrations. This indicates that possible regime differences (e.g. non-homogeneous flow conditions) in the columns may have contributed to the differences observed in pore water PAH concentrations. Inherent localized permeability within the intact cores may be responsible for preferential advective flow through the column and the observed pore water PAH concentration variability between the three cores recovered.

### 6.6.4 Cap Model Results

The ability of organoclay reactive cap to sequester PAHs from pore water was modeled using a Microsoft® Excel spreadsheet (Gardner et al., 2010). This model is based only on the mass of organoclay in Reactive Core Mat™ (3.95 kilograms per square meter [kg/m²]). It does not account for the additional 6-inch-thick sand cover. The adsorption affinities obtained for CETCO organoclay for PAHs during batch experiments were used in this model. The model inputs include pore water PAH concentrations, ESVs, and partition coefficient ( $K_d$ ) values as presented in **Table 6-13**. The model was run for two conditions: high flux (0.29 centimeters per day [cm/d]) with maximum concentrations observed in the field, and low flux (0.029 cm/d) with average concentrations observed in the field for selected PAHs. These analyses were

performed for a period of 50 years. **Table 6-13** presents the observed maximum and average concentrations for selected PAHs used in the model.

**TABLE 6-13**  
Model Inputs for Selected PAHs  
*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*

Parameter	ESV (µg/L)	K <sub>d</sub> (L/kg)	Maximum Pore Water Concentration (µg/L)	Average Pore Water Concentration (µg/L)
Phenanthrene	8.3	14,700	980	131
Naphthalene	1.4	3,240	6000	502
Fluoranthene	11	56,900	170	35

Notes:

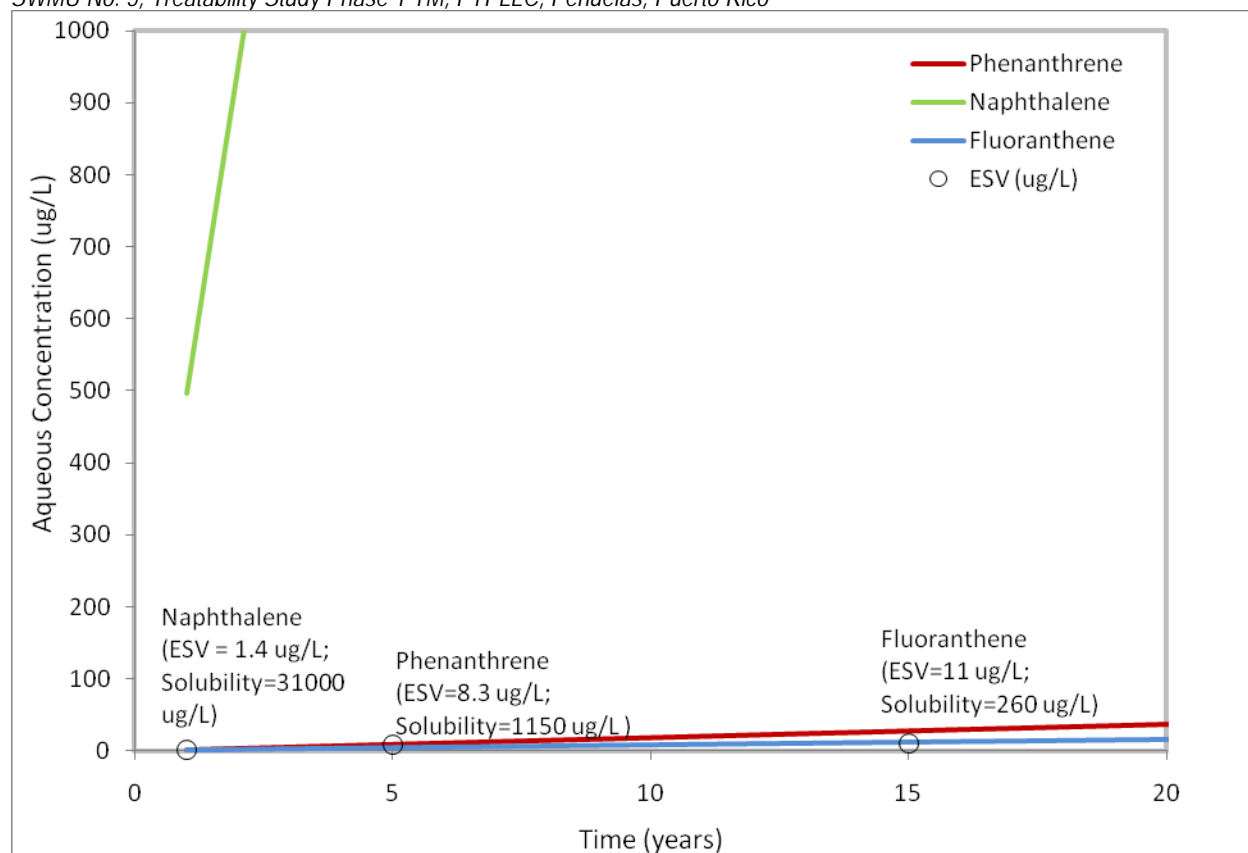
ESV – ecological screening value

L/kg – liters per kilogram

µg/L – micrograms per liter

**Figures 6-3 and 6-4** present the model results. In **Figure 6-3**, results are presented for the model run at higher flux conditions and maximum detected concentrations of selected PAHs to perform a worst-case analysis. This plot compares ESVs of selected PAHs with the treated pore water concentrations and provides information about the time when concentrations passing through the cap will exceed the respective ESVs (small circles).

**FIGURE 6-3**  
 Model Results for High Flux and High Concentration Conditions  
*SWMU No. 5, Treatability Study Phase 1 TM, PTPLLC, Peñuelas, Puerto Rico*

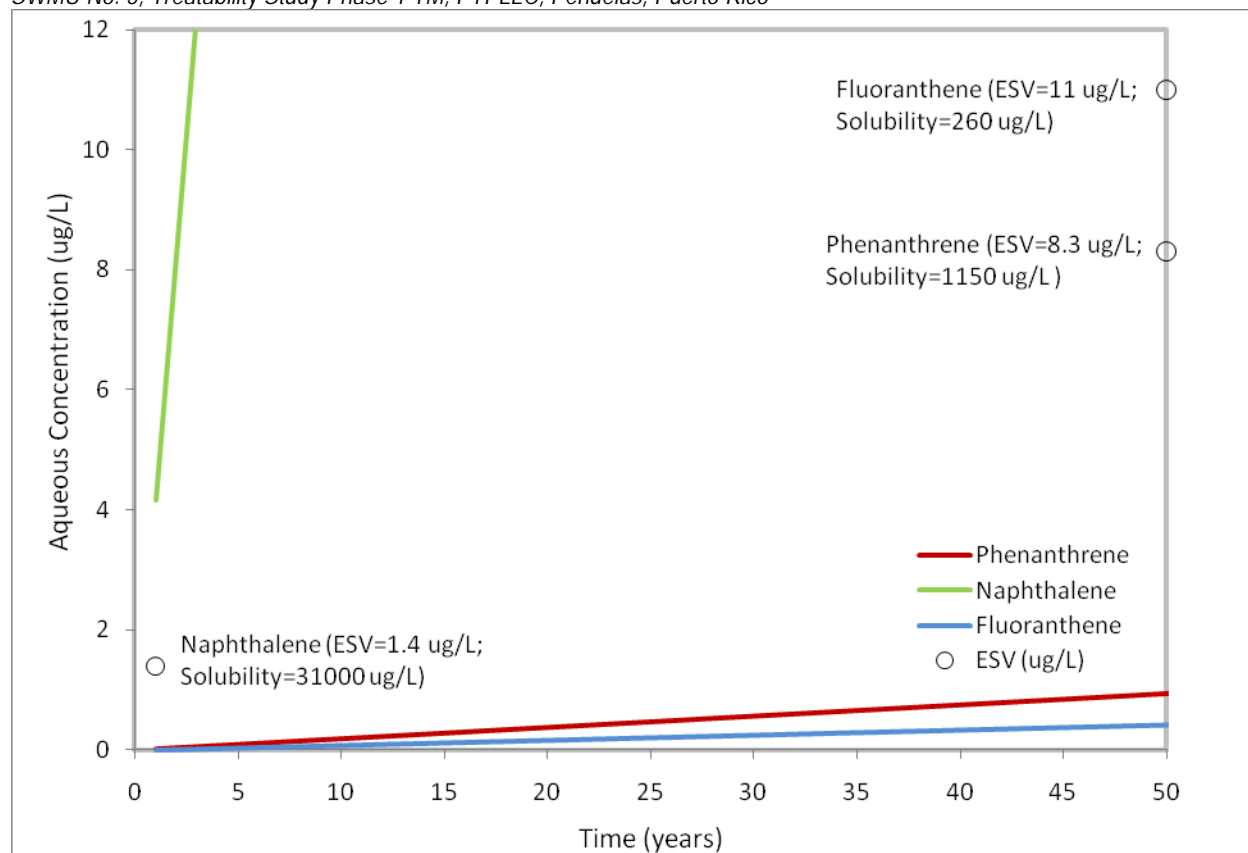


**Figure 6-3** indicates that concentrations may exceed ESVs for naphthalene within a year of cap deployment, for phenanthrene in about 5 years, and for fluoranthene in about 15 years.

In **Figure 6-4**, results are presented for 50 years analysis at low flux conditions and average detected concentrations of selected PAHs to perform a moderate case analysis. This plot also compares ESVs of selected PAHs with the treated pore water concentrations and provides information about the time when concentrations passing through the cap will exceed the respective ESVs (small circles).



**FIGURE 6-4**  
 Model Results for Low Flux and Average Concentration Conditions  
*SWMU No. 5, Treatability Study Phase 1 TM, PTP LLC, Peñuelas, Puerto Rico*



**Figure 6-4** indicates that concentrations of naphthalene passing through the cap may exceed its ESV within a year after cap deployment. The model did not indicate any exceedances for phenanthrene and fluoranthene for their respective ESV within 50 years of cap deployment.

# Conclusion and Recommendations

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## 7.1 Marine Surveys

The Phase 1 bathymetric and sub-bottom profiling data indicate that the proposed Phase 2 pilot study cap and backfill locations are appropriate and free of significant interferences. Additional sonar testing will be performed in Phase 2 to confirm that the proposed cap area is still acceptable. The Phase 1 ADCP current study and water quality monitoring data are adequate for pilot study evaluation.

## 7.2 Geotechnical Data

The geotechnical test data adequately characterize the classification and engineering properties of the onsite sediment and quarry sand materials for use in cap studies. The CPT information supplements RFI data concerning sediment consistency and depth to refusal. The FEM model provides a preliminary depiction of expected settlement resulting from cap placement on the sediment.

The report by Melton (2009) suggested staged construction of cap materials on the underlying sediment to allow for consolidation and strengthening during multi-layer construction. This will be further evaluated after Phase 2 results.

## 7.3 Seepage Flux and Surface Water/Groundwater Interaction

These two studies are related and are considered incomplete in Phase 1. The deployment time and locations for the seepage meters was too limited to provide reliable information as to volume, direction, and variability of flow. The survey information was suspect and water level recordings were unreliable as well. CH2M HILL recommends repetition and/or extension of both activities in Phase 2 for further data collection. Specific recommendations for Phase 2 are as follows:

- Resurvey well casings for F-15, D-22, and Stilling Well to provide a vertical datum for the recording meters.
- Redeploy the recording meters on these three wells to collect simultaneous water level measurements at 5-minute intervals referenced to the newly surveyed vertical datum for a period of at least 2 weeks.
- Redeploy seepage meters at up to eight locations (four in the pilot cap area and four nearby) for periods of at least 5 days each to measure groundwater flux to and from the canal surface water.

## 7.4 Adsorption Testing

Based on the batch isotherm testing (equilibrium adsorption testing), the adsorption affinity of the sand cap material was found to be low. In addition, linear partition coefficients for sand

could not be obtained. The sand cap material is uniform fine sand with very low organic content.

Equilibrium adsorption testing determined a relatively significant adsorption affinity for both CETCO and AquaBlok organoclays in comparison to the sand.

## 7.5 Cap Column Testing

Column results demonstrated that the CETCO Reactive Core Mat™ can be an effective capping material. The AquaBlok cap should provide similar effectiveness to the CETCO material, based on adsorption testing results; however, its effectiveness could not be evaluated properly in the column studies. The pore water concentrations emanating from the sediments to the cap in the AquaBlok column were too low to demonstrate significant reductions.

## 7.6 Cap Modeling

A Microsoft® Excel spreadsheet-based cap model was used to evaluate the performance of CETCO organoclay cap over a period of 50 years. This evaluation was performed for worst-case and moderate-case analyses. Results indicated that depending on the breakthrough criteria, seepage flux conditions, and PAHs concentrations encountered in the field, the life of the cap could vary from 1 year to more than 50 years. Additional modeling will be performed during the CMS to compare the life of different types of caps and to address cap thickness requirements.

The cap models will determine the life of the cap and thickness of reactive layer and sand cover required for effective treatment. Using the cap model, along with bench scale cap performance and pilot scale cap construction studies to evaluate the performance of caps, eliminates the requirement for further post-cap deployment chemical monitoring.

## SECTION 8

# References

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APPENDIX A

# Chain of Custody Documentation

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**UCCLLC SWMU 5**  
**CH2M HILL**  
**Chain of Custody Form**

Project Site		<b>SWMU 5</b>			Number of Containers	Analysis Requested													Project No. 389462	
Project Manager		David Lane				Level #3 QC Data Package	MET_W	TOC_W	TPAH_W	ALK_W								Lab Batch/SDG ID		
Contact Tel No.		352-335-7991																Lab Tel No./Fax No.		
Contact Address		3011 SW Williston Road, Gainesville, FL 32608																(717) 656-2308		
Lab Name		Lancaster Labs, Inc.																		
Lab Contact		Wendy Kozma																		
Lab Address		2425 New Holland Pike Lancaster, PA 17601-5994																		
Item	Sample ID	Station ID	Matrix	Date & Time Collected													Comments			
1	05PW-10	Pore water -10	W	5/20/09 12:10 AM	3	X		1	1	1										
2	05PW-FD2	Field Dupe 2	W	5/20/09 12:00 AM	3	X		1	1	1										
3	05PW-09	Pore water -09	W	5/20/09 12:45 AM	3	X		1	1	1										
4	05PW-08	Pore water -08	W	5/20/09 13:00 AM	3	X		1	1	1										
5	05PW-07	Pore water -07	W	5/20/09 13:25:AM	3	X		1	1	1										
6	05PW-05	Pore water -05	W	5/20/09 15:25 AM	3	X		1	1	1										
7																				
8																				
9																				
10																				
11																				
Sampled By: IL/TW				Date/Time 5-20-09		Custody Seal: Y / N Relinquished By: CH2M HILL										Date/Time:				
Shipped Via: UPS FedEx Hand Other (Please specify):																				
Samples Temperature and Condition Upon Receipt (for lab's use):																				
Received By:			Date/Time:			Custody Seal: Y / N Relinquished By:										Date/Time:				
Received By:			Date/Time:			Custody Seal: Y / N Relinquished By:										Date/Time:				
Remarks: Caution Samples may contain High concentration of contaminate. Heavy Sheen observed on pore water samples.																				

**UCCLLC SWMU 5**  
**CH2M HILL**  
**Chain of Custody Form**

Project Site		<b>SWMU 5</b>			Number of Containers	Analysis Requested													Project No. 389462	
Project Manager		David Lane				Level #3 QC Data Package	MET_W	TOC_W	TPAH_W	ALK_W								Lab Batch/SDG ID		
Contact Tel No.		352-335-7991																Lab Tel No./Fax No.		
Contact Address		3011 SW Williston Road, Gainesville, FL 32608																(717) 656-2308		
Lab Name		Lancaster Labs, Inc.																Comments		
Lab Contact		Wendy Kozma																		
Lab Address		2425 New Holland Pike Lancaster, PA 17601-5994																		
Item	Sample ID	Station ID	Matrix	Date & Time Collected																
1	05PW-04	Pore water -04	W		3	X		1	1	1							see remarks below			
2	05PW-03	Pore water -03	W		3	X		1	1	1							Centrifuge Sample			
3	05PW-02	Pore water -02	W		3	X		1	1	1										
4	05PW-01	Pore water -01	W		3	X		1	1	1										
5	05PW-FD1	Field Dupe 1	W		3	X		1	1	1										
6	05PW-MS	MS	W		3	X		1	1	1							Extra volume for Matrix Spike			
7	05PW-MSD	MSD	W		3	X		1	1	1							Extra volume for Matrix Spike Duplicate			
8																				
9																				
10																				
11																				
Sampled By: IL/TW				Date/Time 5-21-09		Custody Seal: Y / N Relinquished By: CH2M HILL										Date/Time:				
Shipped Via: UPS FedEx Hand Other (Please specify):																				
Samples Temperature and Condition Upon Receipt (for lab's use):																				
Received By:				Date/Time:		Custody Seal: Y / N Relinquished By:										Date/Time:				
Received By:				Date/Time:		Custody Seal: Y / N Relinquished By:										Date/Time:				
Remarks: Caution Samples may contain High concentration of contaminate. Heavy Sheen observed on pore water samples.																				

**UCCLLC SWMU 5**  
**CH2M HILL**  
**Chain of Custody Form**

<b>Project Site</b>		<b>SWMU 5</b>				<b>Number of Containers</b>	<b>Analysis Requested</b>												<b>Project No. 389462</b>	
<b>Project Manager</b>		David Lane					CO (Consolidation)	PE (Permeability)	SH (Shear Strength)										<b>Lab Batch/SDG ID</b>	
<b>Contact Tel No.</b>		352-335-7991																	<b>Lab Tel No./Fax No.</b>	
<b>Contact Address</b>		3011 SW Williston Road, Gainesville, FL 32608																		
<b>Lab Name</b>		Kemron Applied Technologies Group																		
<b>Lab Contact</b>		Tom Jordon																		
<b>Lab Address</b>		1359 A Ellsworth Industrial Blvd, Atlanta, GA 30318																		
<b>Item</b>	<b>Sample ID</b>	<b>Station ID</b>	<b>Matrix</b>	<b>Date &amp; Time Collected</b>														<b>Comments</b>		
1	05-SCU1	05-SCU1	SD	5/16/2009	3	X	X	X										3 - 3"X 6" undisturbed cores		
2	05-SCU2	05-SCU2	SD	5/16/2009	3	X	X	X										3 - 3"X 6" undisturbed cores		
3	05-SCU3	05-SCU3	SD	5/16/2009	3	X	X	X										3 - 3"X 6" undisturbed cores		
4	05-SCU4	05-SCU4	SD	5/16/2009	3	X	X	X										3 - 3"X 6" undisturbed cores		
5																				
6																				
7																				
8																				
9																				
10																				
11																				
<b>Sampled By: IL, BS, CSA</b>				<b>Date/Time:</b>		<b>Custody Seal: Y / N</b>				<b>Relinquished By: CH2M HILL</b>				<b>Date/Time: 05/20/09</b>						
<b>Shipped Via:</b> <input type="checkbox"/> UPS <input type="checkbox"/> FedEx <input type="checkbox"/> Hand <input type="checkbox"/> Other (Please specify):																				
<b>Samples Temperature and Condition Upon Receipt (for lab's use):</b>																				
<b>Received By:</b>				<b>Date/Time:</b>				<b>Custody Seal: Y / N</b>				<b>Relinquished By:</b>				<b>Date/Time:</b>				
<b>Received By:</b>				<b>Date/Time:</b>				<b>Custody Seal: Y / N</b>				<b>Relinquished By:</b>				<b>Date/Time:</b>				
<b>Remarks:</b>																				

**UCCLLC SWMU 5  
CH2M HILL  
Chain of Custody Form**

<b>Project Site</b>		<b>SWMU 5</b>				<b>Number of Containers</b>	<b>Analysis Requested</b>												<b>Project No. 389462</b>	
<b>Project Manager</b>		David Lane					<b>AL (Atterberg Limits)</b>	<b>MC (Moisture Content)</b>	<b>GS (Grain Size)</b>										<b>Lab Batch/SDG ID</b>	
<b>Contact Tel No.</b>		352-335-7991																	<b>Lab Tel No./Fax No.</b>	
<b>Contact Address</b>		3011 SW Williston Road, Gainesville, FL 32608																		
<b>Lab Name</b>		Kemron Applied Technologies Group																		
<b>Lab Contact</b>		Tom Jordon																		
<b>Lab Address</b>		1359 A Ellsworth Industrial Blvd, Atlanta, GA 30318																		
<b>Item</b>	<b>Sample ID</b>	<b>Station ID</b>	<b>Matrix</b>	<b>Date &amp; Time Collected</b>														<b>Comments</b>		
1	05-SCU1	05-SCU1	SD	5/16/2009	1	X	X											1L Jar of sediments		
2	05-SCU2	05-SCU2	SD	5/16/2009	1	X	X											1L Jar of sediments		
3	05-SCU3	05-SCU3	SD	5/16/2009	1	X	X											1L Jar of sediments		
4	05-SCU4	05-SCU4	SD	5/16/2009	1	X	X											1L Jar of sediments		
5	05-SS1	05-SS	SO	5/20/2009	1			X										1 Jar of sand		
6	05-SS2	05-SS	SO	5/20/2009	1			X										1Jar of sand		
7	05-SS3	05-SS	SO	5/20/2009	1			X										1 Jar of sand		
8																				
9																				
10																				
11																				
<b>Sampled By: IL, BS, CSA</b>				<b>Date/Time:</b>		<b>Custody Seal: Y / N</b>				<b>Relinquished By: CH2M HILL</b>				<b>Date/Time: 05/20/09</b>						
<b>Shipped Via:</b> <b>UPS</b> <b>FedEx</b> <b>Hand</b> <b>Other (Please specify):</b>																				
<b>Samples Temperature and Condition Upon Receipt (for lab's use):</b>																				
<b>Received By:</b>				<b>Date/Time:</b>				<b>Custody Seal: Y / N</b>				<b>Relinquished By:</b>				<b>Date/Time:</b>				
<b>Received By:</b>				<b>Date/Time:</b>				<b>Custody Seal: Y / N</b>				<b>Relinquished By:</b>				<b>Date/Time:</b>				
<b>Remarks:</b>																				

**UCCLLC SWMU 5**  
**CH2M HILL**  
**Chain of Custody Form**

Project Site		<b>SWMU 5</b>				Number of Containers	Analysis Requested												Project No. 389462	
Project Manager		David Lane					ELU_W											Lab Batch/SDG ID		
Contact Tel No.		352-335-7991																		
Contact Address		3011 SW Williston Road, Gainesville, FL 32608																		
Lab Name		Lancaster Labs, Inc.																Lab Tel No./Fax No.		
Lab Contact		Wendy Kozma																(717) 656-2308		
Lab Address		2425 New Holland Pike Lancaster, PA 17601-5994																		
Item	Sample ID	Station ID	Matrix	Date & Time Collected														Comments		
1	05-ESW	05-ESW	WS		3	X												2 containers with three bottles each		
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
Sampled By:				Date/Time:		Custody Seal: Y / N				Relinquished By:				Date/Time:						
Shipped Via:    UPS       FedEx       Hand       Other (Please specify):																				
Samples Temperature and Condition Upon Receipt (for lab's use):																				
Received By:				Date/Time:		Custody Seal: Y / N				Relinquished By:				Date/Time:						
Received By:				Date/Time:		Custody Seal: Y / N				Relinquished By:				Date/Time:						
Remarks:																				

**UCCLLC SWMU 5  
CH2M HILL  
Chain of Custody Form**

<b>Project Site</b>		<b>SWMU 5</b>			<b>Number of Containers</b>	<b>Analysis Requested</b>												<b>Project No. 387333</b>	
<b>Project Manager</b>		David Lane															<b>Lab Batch/SDG ID</b>		
<b>Contact Tel No.</b>		352-335-7991															<b>Lab Tel No./Fax No.</b>		
<b>Contact Address</b>		3011 SW Williston Road, Gainesville, FL 32608																	
<b>Lab Name</b>		Lancaster Labs, Inc.																	
<b>Lab Contact</b>		Wendy Kozma																	
<b>Lab Address</b>		2425 New Holland Pike Lancaster, PA 17601-5994																	
<b>Item</b>	<b>Sample ID</b>	<b>Station ID</b>	<b>Matrix</b>	<b>Date &amp; Time Collected</b>													<b>Comments</b>		
1																			
2																			
3																			
4																			
5																			
6																			
7																			
8																			
9																			
10																			
11																			
<b>Sampled By:</b>				<b>Date/Time:</b>		<b>Custody Seal: Y / N</b>		<b>Relinquished By:</b>				<b>Date/Time:</b>							
<b>Shipped Via:</b> UPS       FedEx       Hand       Other (Please specify):																			
<b>Samples Temperature and Condition Upon Receipt (for lab's use):</b>																			
<b>Received By:</b>				<b>Date/Time:</b>		<b>Custody Seal: Y / N Relinquished By:</b>				<b>Date/Time:</b>									
<b>Received By:</b>				<b>Date/Time:</b>		<b>Custody Seal: Y / N Relinquished By:</b>				<b>Date/Time:</b>									
<b>Remarks:</b>																			



**UCCLLC SWMU 5  
CH2M HILL  
Chain of Custody Form**

Project Site		<b>SWMU 5</b>				Data PKG Level	Number of Containers	Analysis Requested												Project No. 389462	
Project Manager		David Lane						ELU_S	TOC_S	TPAH_S									Lab Batch/SDG ID		
Contact Tel No.		352-335-7991																	Lab Tel No./Fax No.		
Contact Address		3011 SW Williston Road, Gainesville, FL 32608																	(717) 656-2308		
Lab Name		Lancaster Labs, Inc.																	Comments		
Lab Contact		Wendy Kozma																			
Lab Address		2425 New Holland Pike Lancaster, PA 17601-5994																			
Item	Sample ID	Station ID	Matrix	Date & Time Collected																	
1	05-SCD1	05-SCD1 (0-6")	SD	5/16/2009 14:00:00 AM	3	1	X	X	X								PAH, TOC and Elutriate testing				
2	05-SCD2	05-SCD2 (0-6")	SD	5/16/09 12:42 AM	3	1		X	X								PAH and TOC				
3	05-SCD3	05-SCD3 (0-6")	SD	5/16/09 12:38 AM	3	1		X	X								PAH and TOC				
4	05-SCD4	05-SCD4 (0-6")	SD	5/16/09 11:46 AM	3	1		X	X								PAH and TOC				
5	05-SCD5	05-SCD5 (0-6")	SD	5/16/09 11:55 AM	3	1		X	X								PAH and TOC				
6	05-SCD6	05-SCD6 (0-6")	SD	5/16/2009 14:10:00 PM	3	1		X	X								PAH and TOC				
7	05-SCD7	05-SCD7 (0-6")	SD	5/16/2009 14:05:00 PM	3	1		X	X								PAH and TOC				
8	05-SCD1 FD1-SD	05-SCD1 (0-6")	SD	5/16/2009 14:00:00 AM	3	1		X	X								Extra sample volume if needed				
9	05-SCD1 MS1-SD	05-SCD1 (0-6")	SD	5/16/2009 14:00:00 AM	3	1		X	X								Extra sample volume if needed				
10	05-SCD1 MSD1-SD	05-SCD1 (0-6")	SD	5/16/2009 14:00:00 AM	3	1		X	X								Extra sample volume if needed				
11																					
Sampled By: IL, BS and CSA				Date/Time:		Custody Seal: Y / N				Relinquished By: CH2M HILL				Date/Time: 05/18/09 12:00 PM							
Shipped Via: UPS FedEx Hand Other (Please specify):																					
Samples Temperature and Condition Upon Receipt (for lab's use):																					
Received By:			Date/Time:			Custody Seal: Y / N Relinquished By:						Date/Time:									
Received By:			Date/Time:			Custody Seal: Y / N Relinquished By:						Date/Time:									
Remarks:																					

**UCCLLC SWMU 5**  
**CH2M HILL**  
**Chain of Custody Form**

Project Site		<b>SWMU 5</b>			Data PKG Level	Number of Containers	Analysis Requested														Project No. 389462	
Project Manager		David Lane					ELU_S	TOC_S	TPAH_S										Lab Batch/SDG ID			
Contact Tel No.		352-335-7991																	Lab Tel No./Fax No.			
Contact Address		3011 SW Williston Road, Gainesville, FL 32608																	(717) 656-2308			
Lab Name		Lancaster Labs, Inc.																				
Lab Contact		Wendy Kozma																				
Lab Address		2425 New Holland Pike Lancaster, PA 17601-5994			Comments																	
Item	Sample ID	Station ID	Matrix	Date & Time Collected																		
1	05-EB-SD	FIELDQC	WQ	5/18/09 0:00	3	2		X	X									Equipment Blank for Sediment Samples				
2																						
3																						
4																						
5																						
6																						
7																						
8																						
9																						
10																						
11																						
Sampled By: IL, BS and CSA				Date/Time:		Custody Seal: Y / N				Relinquished By: CH2M HILL				Date/Time: 05/18/09 12:00 PM								
Shipped Via: UPS    FedEx    Hand    Other (Please specify):																						
Samples Temperature and Condition Upon Receipt (for lab's use):																						
Received By:				Date/Time:		Custody Seal: Y / N				Relinquished By:				Date/Time:								
Received By:				Date/Time:		Custody Seal: Y / N				Relinquished By:				Date/Time:								
Remarks:																						

**UCCLLC SWMU 5  
CH2M HILL  
Chain of Custody Form**

Project Site		<b>SWMU 5</b>			Number of Containers	Analysis Requested												Project No. 387333		
Project Manager		David Lane				CCS_W													Lab Batch/SDG ID	
Contact Tel No.		352-335-7991																		
Contact Address		3011 SW Williston Road, Gainesville, FL 32608																		
Lab Name		University of New Hampshire																		Lab Tel No./Fax No.
Lab Contact		Kevin Gardner																		(603) 862-4334
Lab Address		336 Gregg Hall, 35 Colovos Rd, Durham, NH 03824																		
Item	Sample ID	Station ID	Matrix	Date & Time Collected														Comments		
1	05-CCS-W	05-PW	WS	5/20/2009	2	X												2 - 2.5 gallons plastic containers		
2	05-CCS-W	05-PW	WS	5/20/2009	1	X												1 - 5 gallons plastic container		
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
Sampled By: IL/ TW				Date/Time: 05/20/09		Custody Seal: Y / N				Relinquished By: CH2M HILL				Date/Time: 05/21/09						
Shipped Via: UPS    FedEx    Hand    Other (Please specify):																				
Samples Temperature and Condition Upon Receipt (for lab's use):																				
Received By:				Date/Time:				Custody Seal: Y / N Relinquished By:				Date/Time:								
Received By:				Date/Time:				Custody Seal: Y / N Relinquished By:				Date/Time:								
Remarks:																				

**UCCLLC SWMU 5  
CH2M HILL  
Chain of Custody Form**

<b>Project Site</b>		<b>SWMU 5</b>			<b>Number of Containers</b>	<b>Analysis Requested</b>												<b>Project No. 387333</b>											
<b>Project Manager</b>		David Lane				<b>CCS_W</b>												<b>Lab Batch/SDG ID</b>											
<b>Contact Tel No.</b>		352-335-7991																<b>Lab Tel No./Fax No.</b>											
<b>Contact Address</b>		3011 SW Williston Road, Gainesville, FL 32608																(603) 862-4334											
<b>Lab Name</b>		University of New Hampshire																<b>Comments</b>											
<b>Lab Contact</b>		Kevin Gardner																											
<b>Lab Address</b>		336 Gregg Hall, 35 Colovos Rd, Durham, NH 03824																											
<b>Item</b>	<b>Sample ID</b>	<b>Station ID</b>	<b>Matrix</b>	<b>Date &amp; Time Collected</b>																									
1	05-PW12	05-PW12	WS		1													X											
2	05-PW13	05-PW13	WS		1	X																							
3	05-PW14	05-PW14	WS		1	X																							
4																													
5																													
6																													
7																													
8																													
9																													
10																													
11																													
<b>Sampled By:</b>				<b>Date/Time:</b>		<b>Custody Seal: Y / N</b>		<b>Relinquished By:</b>		<b>Date/Time:</b>																			
<b>Shipped Via:    UPS       FedEx       Hand       Other (Please specify):</b>																													
<b>Samples Temperature and Condition Upon Receipt (for lab's use):</b>																													
<b>Received By:</b>				<b>Date/Time:</b>		<b>Custody Seal: Y / N   Relinquished By:</b>				<b>Date/Time:</b>																			
<b>Received By:</b>				<b>Date/Time:</b>		<b>Custody Seal: Y / N   Relinquished By:</b>				<b>Date/Time:</b>																			
<b>Remarks:</b>																													

**SWMU 5**  
**CH2M HILL**  
**Chain of Custody Form**

Project Site		<b>SWMU 5</b>				Number of Containers		Analysis Requested												Project No. 389462				
Project Manager		David Lane						Sand Sample														Lab Batch/SDG ID		
Contact Tel No.		352-335-7991																						
Contact Address		3011 SW Williston Road, Gainesville, FL 32608																					Lab Tel No./Fax No.	
Lab Name		University of New Hampshire																					(603) 862-4334	
Lab Contact		Kevin Gardner																					Comments	
Lab Address		336 Gregg Hall, 35 Colovos Rd, Durham, NH 03824																						
Item	Sample ID	Station ID	Matrix	Date & Time Collected																				
1	05-SS1	05-SS1 (5 Gallons)	SS	5/18/2009	1	X															Sand Cap Material			
2																								
3																								
4																								
5																								
6																								
7																								
8																								
9																								
10																								
11																								
Sampled By:				Date/Time:		Custody Seal: Y / N		Relinquished By: CH2M HILL				Date/Time: 05/18/09												
Shipped Via:    UPS       FedEx       Hand       Other (Please specify):																								
Samples Temperature and Condition Upon Receipt (for lab's use):																								
Received By:				Date/Time:		Custody Seal: Y / N				Relinquished By:				Date/Time:										
Received By:				Date/Time:		Custody Seal: Y / N				Relinquished By:				Date/Time:										
Remarks:																								

**SWMU 5  
CH2M HILL  
Chain of Custody Form**

Project Site		<b>SWMU 5</b>				Number of Containers	Analysis Requested												Project No. 389462	
Project Manager		David Lane					CCS_S	GCS_S	Sand Sample										Lab Batch/SDG ID	
Contact Tel No.		352-335-7991																	Lab Tel No./Fax No.	
Contact Address		3011 SW Williston Road, Gainesville, FL 32608																	(603) 862-4334	
Lab Name		University of New Hampshire																	Comments	
Lab Contact		Kevin Gardner																		
Lab Address		336 Gregg Hall, 35 Colovos Rd, Durham, NH 03824																		
Item	Sample ID	Station ID	Matrix	Date & Time Collected																
1	05-CS1	05-CS1 (6"X12")	SD	5/15/09 15:13	1	X												Column capping studies		
2	05-CS2	05-CS2 (6"X12")	SD	5/16/09 10:02	1	X												Column capping studies		
3	05-CS3	05-CS3 (6"X12")	SD	5/16/09 15:15	1	X												Column capping studies		
4	05-GT1	05-GT1 (3"X12")	SD	5/16/09 12:23	1		X											Geotechnical Testing		
5	05-GT2	05-GT2 (3"X12")	SD	5/16/09 12:05	1		X											Geotechnical Testing		
6																				
7																				
8																				
9																				
10																				
11																				
Sampled By: IS, BS, CSA				Date/Time:		Custody Seal: Y / N				Relinquished By: CH2M HILL				Date/Time: 05/18/09						
Shipped Via: UPS    FedEx    Hand    Other (Please specify):																				
Samples Temperature and Condition Upon Receipt (for lab's use):																				
Received By:			Date/Time:			Custody Seal: Y / N						Relinquished By:			Date/Time:					
Received By:			Date/Time:			Custody Seal: Y / N						Relinquished By:			Date/Time:					
Remarks:																				

## Analytical Data Quality Reports

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## Data Validation Summary

### Penuelas Technology Park, LLC

### SWMU 5

TO: David Lane/CH2M HILL/GNV

FROM: Tiffany McGlynn/CH2M HILL/GNV  
Ward Dickens/CH2M HILL /GNV

DATE: October 12<sup>th</sup>, 2010

The purpose of this memorandum is to present the results of the data validation process for the samples collected for Penuelas Technology Park, LLC site located in Penuelas, Puerto Rico. The samples were collected in May 2009.

The Quality Control areas that were reviewed and the resulting findings are documented within each subsection that follows. This data was validated for compliance with the cited analytical method requirements. This process also included a review of the data to assess the accuracy, precision, and completeness based upon procedures described in the guidance documents including the Environmental Protection Agency (EPA) National Functional Guidelines for Organic Data Review (EPA 1999), the EPA National Functional Guidelines for Evaluating Inorganic Analysis (EPA 2002), and the criteria presented in the Dow Midland Program Quality Assurance Project Plan (QAPP) (CH2M HILL 2004). The Quality assurance/Quality control (QA/QC) summary forms and data reports provided by the laboratory were reviewed.

Soil and water samples were submitted to Lancaster Laboratories, Inc. for the analyses listed below.

- PAH Semivolatiles by Method SW-846 8270C
- Metals by Method SW-846 6010B
- Mercury by Method SW-846 7470A
- Total Organic Carbon by Method SM20 5310C and Lloyd Kahn
- Alkalinity by Method SM20 2320B

During the data review and validation process, sample results that were not within the acceptance limits were appended with a primary qualifying flag to indicate a problem with the data and a secondary sub-qualifier flag (validation reason code) to provide the reasoning behind the assignment of a qualifier to the data. The secondary qualifiers and their definitions are found in **Attachment 1**.

The following primary flags were used to qualify the data:

- [=] Detected. The analyte was detected at the concentration shown.
- [J] Estimated. The analyte was present but the reported value may not be accurate or precise.
- [U] Not detected. The analyte was not detected above the method detection limit.
- [UJ] Not detected, estimated. The analyte was qualified as not detected and the result is estimated.
- [R] Rejected. The data is not useable.
- [X] Excluded. Data not used due to dilution or reanalysis, and another value is more appropriate.

## Quality Control Review

The following list represents the QA/QC measures that were reviewed during the data quality evaluation process.

### Holding Times

Each sample must be analyzed within a method specified holding time.

All holding time criteria were met.

### Blank Samples

For the organic analyses, method blanks (MB) and equipment blanks (EB) were provided. For the inorganic analysis, MB, EB, and initial and continuing calibration blanks (ICB/CCB) were provided. Blank samples enable the reviewer to determine if an analyte may be attributed to sampling or laboratory procedures, rather than environmental contamination from site activities.

Blank samples were analyzed for each parameter at the required frequency and were evaluated.

Various metals were detected in initial and continuing calibration blanks for water samples. Mercury was detected in the method blank for water samples. TOC was detected in the equipment blank for soil samples. Affected data are summarized in **Attachment 2**.

### Surrogate Recoveries

Surrogate spikes consist of organic compounds which are similar in chemical composition and behavior to the method target compounds, but which are not normally found in environmental samples. Surrogate compounds are added to each sample and the recoveries are used to monitor lab performance and possible matrix interference.

All surrogate criteria were met.

### Lab Control Sample/Lab Control Sample Duplicate (LCS/LCSD)

These samples are quality control samples, spiked with a known concentration of target analytes, utilized to monitor laboratory method performance. The accuracy and

precision of the LCS/LCSD indicate whether the analytical method was in control. Additionally, these measurements serve as a monitor of the overall performance of each step during the analysis, including sample preparation. The samples do not possess a difficult matrix as they consist of deionized laboratory water spiked with target compounds of interest.

All LCS/LCSD criteria were met with the exception of fluorene and fluoranthene which both exhibited recoveries above the control limits for soil samples. Affected data are summarized in **Attachment 2**.

### **Matrix Spike/Matrix Spike Duplicate (MS/MSD)**

This is an aliquot of sample spiked with a known concentration of target analytes. Spike recoveries are used to evaluate potential matrix interferences, as well as accuracy and precision pertaining to each specific matrix.

All MS/MSD criteria were met with the exception of various compounds for PAHs for both soil and water samples as well as TOC for water samples. Several compounds for PAHs in both soil and water exhibited recoveries either above or below the control limits as well as relative percent difference (RPD) above criteria. TOC exhibited recoveries below the lower control limits.

Affected data are summarized in **Attachment 2**.

### **Field Duplicate Samples**

These samples measure field and laboratory precision as well as sample homogeneity. This information can only be determined when target compounds are detected.

The field duplicate precision for each parameter was evaluated according to requirements presented in the QAPP.

Various compounds in PAHs as well as TOC for water samples did not meet precision criteria. Affected data are summarized in **Attachment 2**.

### **Rejected Data**

There were no data rejected such that there is not a valid result for each sample and parameter.

### **Conclusion**

A review of the analytical data submitted for the Penuelas Technology Park, LLC site located in Penuelas, Puerto Rico has been completed. An overall evaluation of the data indicates that the sample handling, shipment, and analytical procedures have been adequately completed. The validation review demonstrated that the analytical systems were generally in control and the data results can be used in the project decision making process.

Attachment 1  
Validation Reason Codes

Validation Code	Definition
2SH	Second source calibration verification standard greater than the upper control limit
2SL	Second source calibration verification standard less than the lower control limit
ABH	Ambient blank concentration greater than the RL
ABL	Ambient blank concentration less than the RL
BKD	The result is qualified because the DDT and/or Endrin breakdown was greater than 20%.
CBKD	The result is qualified because the combined DDT/Endrin breakdown is greater than 30%.
CCBH	Continuing calibration blank concentration greater than the RL
CCBL	Continuing calibration blank concentration less than RL
CCC	CCC Failure
CCRRF	Continuing calibration relative response factor below the LCL
CCVF	Continuing Calibration not analyzed at the required frequency
CCVH	Continuing calibration recovery greater than upper control limit
CCVL	Continuing calibration recovery less than lower control limit
CF	Confirmation result
CFP	Confirmation precision exceeded
CO	Compounds were reported combined on one column
DL	Secondary dilution
EBH	Equipment blank concentration greater than the RL
EBL	Equipment blank concentration less than the RL
EMPC	Estimated Maximum Possible Concentration Reported
FBH	Field blank concentration greater than the RL
FBL	Field blank concentration less than the RL
FD	Field duplicate exceeds RPD criteria
GPC	The results are qualified due to GPC calibration deficiencies.
HTA	Analytical Holding Time exceeded
HTP	Preparation Holding Time exceeded
IB	Result between the MDL and RL
ICBH	Initial calibration blank concentration greater than the RL
ICBL	Initial calibration blank concentration less than RL
ICR2	Initial calibration exceeded the R2 for first order regression
ICRR	Exceeds RSD criteria and initial calibration exceeded the R2 for first order regression
ICRRF	Initial calibration relative response factor below the LCL
ICRSD	Initial calibration RSD exceeded
ICSH	Interference present and %recovery is greater than upper control limit
ICSL	Interference present and %recovery is less than lower control limit
ICSP	Single Point Initial Calibration used for Quantitation
ICVH	Initial calibration recovery exceeds the upper control limit
ICVL	Initial calibration recovery exceeds the lower control limit
ICVSH	Initial calibration verification recovery greater than upper control limit
ICVSL	Initial calibration verification recovery less than lower control limit
ISH	Internal standard response exceeded the UCL criteria
ISL	Internal standard response exceeded the LCL criteria
LBH	Laboratory blank contamination greater than the RL
LBL	Laboratory blank contamination less than the RL
LCSDH	LCSD recovery greater than criteria
LCSDL	LCSD recovery less than the criteria
LCSH	LCS recovery greater than criteria
LCSL	LCS recovery less than the criteria
LCSP	LCS/LCSD RPD criteria exceeded
LDP	Laboratory Duplicate Precision out
LR	Linear range exceeded. Concentration above linear range.
MSA	Quantitated by the method of standard additions
MSALL	Global matrix spike flagging
MSAR2	method of standard additions R2 out
MSDH	Matrix spike duplicate recovery criteria greater than the upper limit

Attachment 1  
Validation Reason Codes

Validation Code	Definition
MSDL	Matrix spike duplicate recovery criteria less than the lower limit
MSDP	Matrix Spike Duplicate RPD criteria exceedance
MSH	Matrix spike recovery criteria greater than the upper limit
MSL	Matrix spike recovery criteria less than the lower limit
NMS	Not Site-specific Matrix Spike
PH	Sample pH out. Not properly preserved.
PRM	Result differs from Preliminary Result
PSH	Post spike recovery criteria greater than the upper limit
PSL	Post spike recovery criteria less than the lower limit
RA	Sample was reanalyzed
RE	Sample was re-extracted and reanalyzed
RT	Result is outside the laboratory determined retention time window
SCRN	Screening method and/or data
SDIL	Serial Dilution %D exceeds the upper control limit
SPCC	SPCC Failure
SSH	Surrogate recovery greater than upper limit
SSL	Surrogate recovery less than lower limit
SSR	Surrogate spike recovery <10%
TBH	Trip blank concentration greater than the RL
TBL	Trip blank concentration less than the RL
TD	Total Concentration < Dissolved Concentration
TEMP	Cooler temperature out upon arrival
TIC	Tentatively identified compound
TN	GC/MS tune does not meet criteria
XCC	No Continuing Calibration analyzed in the analytical batch
X-DL	Data not used due to dilution; another value is more appropriate or data was not requested
XIC	No initial calibration analyzed in the analytical batch
XICVS	Initial calibration verification standard was not analyzed
XLCS	No LCS in the analytical batch
XLD	Laboratory Duplicate not reported
XMS	Matrix Spike not reported
XMSD	Matrix Spike Duplicate not reported
X-RE	Data not used due to reanalysis another value is more appropriate or data was not requested
XICS	No interference check standard in analytical batch
XSDIL	No Serial Dilution in the analytical batch

Matrix	SDG	Parameter Class	Analytical Method	Sample ID	Parameter	Lab Result	Lab Qual	Final Result	Final Qual	Units	Validation Notes
WS	CSR02	METALS	SW6010B	05PW-07	Arsenic	0.01	J	0.01	U	mg/L	CCBL
WS	CSR02	METALS	SW7470A	05PW-03	Mercury	0.00013	J	0.00013	U	mg/L	CCBL,LBL
WS	CSR02	METALS	SW7470A	05PW-07	Mercury	0.00026	=	0.00026	U	mg/L	CCBL,LBL
WS	CSR02	GENCHEM	A2320B	05PW-10	Alkalinity to pH 4.5	132	=	132	J	mg/L	FD
WS	CSR02	GENCHEM	A5310C	05PW-FD1	Total organic carbon	3.4	=	3.4	J	mg/L	FD
WS	CSR02	GENCHEM	A2320B	05PW-FD2	Alkalinity to pH 4.5	226	=	226	J	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-01	Naphthalene	0.001	U	0.001	UJ	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-01	Chrysene	0.001	U	0.001	UJ	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-01	1-methylnaphthalene	0.001	U	0.001	UJ	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-01	2-Methylnaphthalene	0.001	U	0.001	UJ	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-10	1-methylnaphthalene	0.016	=	0.016	J	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-10	Naphthalene	0.001	U	0.001	UJ	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-FD1	Pyrene	0.018	=	0.018	J	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-FD1	Phenanthrene	0.088	=	0.088	J	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-FD1	Acenaphthylene	0.049	=	0.049	J	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-FD1	Anthracene	0.012	=	0.012	J	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-FD1	Chrysene	0.006	=	0.006	J	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-FD1	Fluorene	0.048	=	0.048	J	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-FD1	Fluoranthene	0.013	=	0.013	J	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-FD1	2-Methylnaphthalene	0.029	=	0.029	J	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-FD1	Naphthalene	0.006	=	0.006	J	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-FD1	Acenaphthene	0.029	=	0.029	J	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-FD1DL	1-methylnaphthalene	0.14	=	0.14	J	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-FD2	1-methylnaphthalene	0.006	=	0.006	J	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-FD2	Naphthalene	0.011	=	0.011	J	mg/L	FD
WS	CSR02	SVOC	SW8270C	05PW-01	Acenaphthene	0.005	=	0.005	J	mg/L	FD,MSDH,MSDP
WS	CSR02	SVOC	SW8270C	05PW-01	Acenaphthylene	0.006	=	0.006	J	mg/L	FD,MSDH,MSDP,MSH
WS	CSR02	GENCHEM	A5310C	05PW-01	Total organic carbon	1.9	=	1.9	J	mg/L	FD,MSL
WA	CSR01	SVOC	SW8270C	05-SCD1-ELU	Fluorene	47	=	47	J	ug/L	LCSDH,LCSH
SD	CSR01	SVOC	SW8270C	05-SCD1	Benzo(b)fluoranthene	7600	=	7600	J	ug/Kg	MSDH
SD	CSR01	SVOC	SW8270C	05-SCD1DL	Benzo(a)pyrene	9000	=	9000	J	ug/Kg	MSDH
SD	CSR01	SVOC	SW8270C	05-SCD1DL	Chrysene	15000	=	15000	J	ug/Kg	MSDL,MSDP

# Product Specification Sheets

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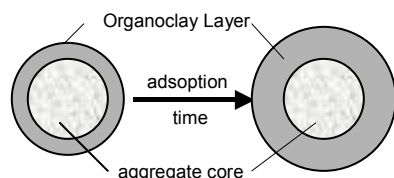
## SPECIFICATION SHEET #13

### AquaGate+ORGANOCCLAY™

### PROVEN REMEDIATION PERFORMANCE OF ORGANOCCLAY DELIVERED IN AN AQUATIC SETTING

#### Background

AquaBlok® is a patented, composite-aggregate technology resembling small stones and typically comprised of a dense aggregate core. In this application of the technology an organoclay coating is utilized with polymers (Figure 1). In other AquaGate+ applications various alternative treatment materials can be incorporated to meet project-specific needs.



**Figure 1. Configuration of an Organoclay Coated Particle.**

AquaGate+ORGANOCCLAY particles adsorb oil and a wide range of hydrocarbon-based contaminants when contact is made in sediments. As the particles chemically bind the contaminants, the clay layer will expand. At a point when the full mass of the organoclay is achieved the particles coalesce into a continuous and relatively soft body of material, decreasing the permeability of the layer. The AquaGate+ORGANOCCLAY layer can also be used in conjunction with a standard AquaBlok cap layer to form an even lower permeability barrier layer above the sediment, if desired.

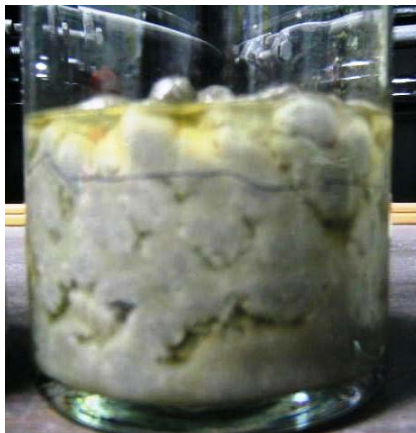
Organoclays are organically modified clays, typically produced by blending surfactants and clay minerals. This blend creates a new product, a surfactant with a solid base. By means of a partition process, the modified clays will fix non-polar organic compounds. In contrast to activated carbon, by which organic compounds are adsorbed into pores in the carbon and quickly become fouled, the partitioning phenomena takes place outside of the clay particles, minimizing the fouling problem.

#### Applications of AquaGate+ORGANOCCLAY Technology

Organoclays are a proven remediation technology that addresses a wide range of hydrocarbon-based contamination. The following is a partial list of typical sites and/or contaminants where AquaGate+ORGANOCCLAY cap can be a cost-effective solution:

- **MGP Plants,**
- **Wood Treating Facilities,**
- **Creosote,**
- **Coal Tar (BTEX),**
- **PCBs,**
- **PAHs / NAPL**

Although it has been established that similar weight of organoclay materials will remove, by means of partitioning, up to 7 times the rate of activated carbon, activated carbon can provide further absorption of trace amounts that may not be fully removed by organoclay. Thus, the materials can be used in series in a complimentary manner in some applications requiring very low levels



**Photo 1. Example Design Mix – 300g of AquaGate+ORGANOCCLAY 4060 Blend Sample (120g of Active Organoclay), 3wks After Addition of 185ml Motor Oil.**

of treatment.

Generally, AquaGate+ORGANOCCLAY is expected to adsorb between 50-100% of the total weight of the organoclay present in the particle. This percentage of organoclay can vary from 20-40% depending on the desired cap / treatment design and contaminant material and concentration.

Additionally, by varying aggregate particle size, control over various properties of the cap can be obtained, thus creating a more versatile cap that can be easily engineered for project specific applications.

#### Use of AquaGate+ORGANOCCLAY

For many projects, use of the product will generally involve applying dry masses of the material through the water and across the surface of contaminated sediments or directly onto pools of free product. The material can also be placed below other more permeable capping materials such as sand or directly on soil/sediments in the dry if an area has been dewatered.

The use of organoclay in an AquaBlok matrix provides for an efficient delivery and placement option for materials that may otherwise be subjected to erosion by stream flow, wave action, or tidal fluctuations.

A variety of application methods have been implemented for similar materials, such as: barges, clamshells, stone slingers, conveyors, and many more. The ease of placement and ability to place AquaGate+ORGANOCCLAY through a water column creates a practical method for addressing sediments contaminated by oils, PCBs or other difficult hydrocarbon based COCs.

#### Funnel & Gate Approach

An AquaGate+ORGANOCCLAY cap can be configured as a “gate” with a “funnel and gate” system to selectively capture discharges from submerged seeps of upland plume related discharges. Should breakthrough eventually occur, the gate material can be effectively removed and the gate replaced with fresh material. By capturing the product at the seep source, relatively modest volumes of material need to be handled as opposed to using oil sorbent booms and pads, etc. to capture and cleanup seeps that discharge through the water and rise to the surface.

#### AquaGate+ORGANOCCLAY Compatible Product Manufacturers

AquaGate+ORGANOCCLAY has been produced and tested with organoclay product available from the following manufacturers:

- **Aqua Technologies of Wyoming, Inc.**
- **Biomin, Inc.**
- **CETCO (Div. of Amcol, Intl.)**
- **Polymer Ventures, Inc.**

In addition, AquaGate+ORGANOCCLAY material can be manufactured with other amendments, such as Adventus Group's ZVI or EHC products (see [www.adventusgroup.com](http://www.adventusgroup.com)), to be used to deliver a treatment “train” approach for complex sediments with multiple contaminants.

## Bench-Scale Testing & Application and Modeling

While organoclays were originally developed as a water treatment medium, they have more recently received consideration for sediment remediation applications, and when delivered to the sediment water interface as an AquaGate+™ amendment, the range of applications increases. In addition, when used in the manufacture of AquaGate+ ORGANOCCLAY, cost efficiencies can be realized as a result of the more effective placement option.

Although other variations exist, the typical applications of AquaGate+ ORGANOCCLAYS would be one of the following:

- A composite cap with AquaGate+ORGANOCCLAY overlain by sand or other non-reactive material can be an effective remedy where contaminated sediments were transplanted to a deposition area that is not related to a continuous upland source.
- A composite cap with AquaGate+ORGANOCCLAY used to consolidate semi-suspended sediments (especially those with petrochemical components) prior to the application of a low permeability standard AquaBlok® cap layer.
- As a treatment gate material in a "funnel and gate" configuration with standard AquaBlok or other low permeable capping material to direct flow through the AquaGate+ ORGANOCCLAY treatment media, either through gate columns set at specific intervals, or laterally under a complete cap for capture along the entire cap length, essentially creating a long, thin horizontal column with significant residence times.

There are multiple manufacturers of organically modified clays and the individual products demonstrate different performance attributes as the chemicals of concern, levels of contamination, and salinity of the application area vary. In addition, different organoclays demonstrate varying swell factors, which are an important design consideration. AquaGate+ORGANOCCLAY has been successfully manufactured using a variety of organoclays from multiple vendors. **Table 1 & 2** demonstrates the relative efficiency of one such product (manufactured by Biomin, Inc.) at removing a surrogate vegetable oil in a series of three small column tests designed to demonstrate the effect of varying particle size (and resulting pore size and volume) and residence time, (which is a function of flow-through rates and column length). **Figure 2** graphically

demonstrates this relationship between particle size (a 1/4" particle size vs. 3/8" particle size) and, in the case of the duplicate 3/8" particles, runs at different flow-through rates and how these variables affect the removal efficiency and the ultimate time (and pore volumes) for significant contaminant breakthrough.

The use of specifically designed bench scale tests can be very effective at selecting specific organoclays for particular applications (see Reible et al, University of Texas at Austin, *Organoclay Laboratory Study – McCormick & Baxter*, September 2005) and the selection of the appropriate AquaGate+ particle size

and layer thickness. Similarly, simple bench scale testing can also determine the appropriate application rates of specific AquaGate+ORGANOCCLAY applications for use as a flocculant to consolidate free-product layers and semi-suspended sediments to facilitate more efficient removal by dredging or excavation, or to create a stable base prior to the installation of a clean cap to meet restoration goals.

The results of bench scale testing can be used in conjunction with flow models to design composite systems that meet long-term risk assessment goals and subsequent targeted remediation goals, while minimizing overall project costs.

Table 1 (\*)

Sorbent	Mass Sorbent		Porosity	Flowrate		Residence
	(kg)	(lb)		(mL/min)	(gal/hr)	
A	0.16	0.34	0.19	2.4	0.038	30
B	0.155	0.341	0.21	7.0	0.114	10
C	0.157	0.345	0.20	3.8	0.061	21

Table 2 (\*)

Sorbent	Breakthrough			Mass Sorbent		Mass Sorbed/Mass Sorbent		
	PV	BV	min	(kg)	(lb)	(mg/kg)	(lb/lb)	(% by sorbent)
A	207.7	39.5	6471	35687	0.079	223043	0.223	22.3
B	101.9	20.4	4256	15702	0.035	98139	0.098	9.8
C	117	23.6	9526	24518	0.054	156163	0.156	15.6

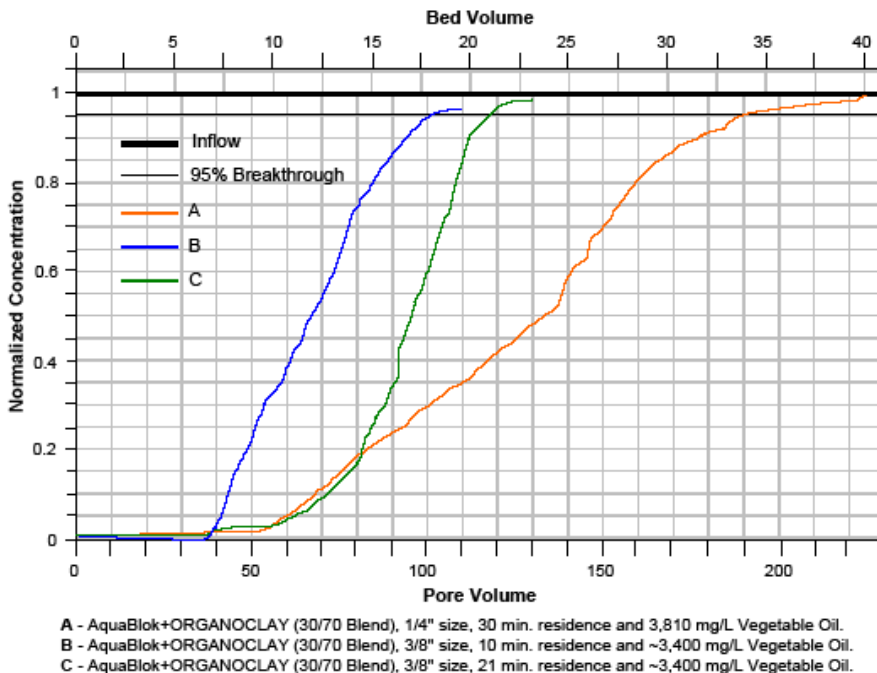


Figure 2. Example Design Mix Variables (\*)

(\*) Independent testing completed by Vinka Cramer, Ph.D. and James Smith, Ph.D. for Biomin, Inc. on sample AquaGate+ORGANOCCLAY material, manufactured by AquaBlok, Ltd. using a Biomin, Inc. supplied Organoclay.

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## TEST REPORT #. 9

### Physical Product Characteristics in Saline Waters

#### Background and Purpose of Testing

Freshwater compatible (sodium bentonite-based) AquaBlok typically displays significant primary pore infilling and net vertical expansion when hydrated in fresh water, as described in Test Report No.6. This is because of the dominant clay's (sodium montmorillonite) plate-like structure, highly charged surface area, and great affinity for water - attributes that, in low-salinity environments, result in the clay's dispersed, physically expanded state.

While significant dispersion and expansion of this clay material in low-salinity waters is well recognized and is, in fact, a key principle behind the functioning of environmental barriers like slurry cutoff walls, equally notable is the relative *lack* of sodium bentonite's expansion in saline waters and in some chemically aggressive waters (e.g. Tobin and Wild 1986; Shackelford 1994). Sodium Bentonite's solution-dependent behavior, as illustrated in Photograph 1, is due to montmorillonite's tendency to flocculate rather than disperse in the presence of high ionic-strength solutions.

Sodium bentonite's sensitivity to high ionic-strength waters is also dynamic. The introduction of highly saline or chemically aggressive waters into an initially dispersed slurry wall system, for example, can result in clay flocculation, increased permeability and, in extreme cases, wall failure (Birdwell 2001; D'Appolonia and Ryan 1979; Day 1994).

Other types of clay minerals display a much lower sensitivity to high ionic-strength waters, or to changes in water chemistry over time. One such mineral is attapulgite (a.k.a. palygorskite). Attapulgite has a needle-like structure, a relatively high but minimally charged surface area, and a lower affinity for water - attributes that result in this mineral displaying minimal flocculation or swelling potential, regardless of the chemistry or salinity level of the hydrating water (e.g. Tobin and Wild 1986; Shackelford 1994). Attapulgite's markedly independent behavior with respect to ionic strength or salinity effects is demonstrated in Photograph 2.

Because of its attributes, and the fact that attapulgite can provide for adequately low and stable hydraulic conductivity (see Test Report No. 10), its use in various environmental barriers is increasing (Birdwell 2001; Day 1994; Galan 1996; Murray 2000). Attapulgite's recognized performance in high saline and other chemically aggressive waters form the basis for its inclusion into some saline formulations of the AquaBlok product.

Published literature also points to advantages associated with using *blends* of clays, like attapulgite plus sodium bentonite, in some environmental barrier systems (Murray 2000; Stern and Shackelford 1998), thus providing justification for including similar blends in other saline formulations of the product.

Calcium bentonite is another type of clay rich material that, similar to attapulgite, tends to show relatively less reactivity (and greater stability) when contacted with high ionic-strength and chemically aggressive waters than does its sodium-rich counterpart (e.g. Alexiew 2000; Koch 2002). As a result of such properties, calcium-rich bentonites are more often being considered for use in environmental barriers (e.g. Dananaj et al., 2005; Koch 2002). Laboratory based experimentation on the relative effectiveness of calcium bentonite-based AquaBlok products and their potential use in saline environments is ongoing.

Physical compaction or loading of barrier materials placed into terrestrial environments (e.g. landfills, subterranean disposal facilities, etc.) can significantly reduce primary porosity, thereby reducing hydraulic conductivity and increasing barrier effectiveness (Shackelford 1994; Daniel 1994; Komine 2004). The concept of increasing barrier effectiveness through loading should also apply to subaqueous environmental barriers as well, despite the countering influence of buoyancy effects. Empirical laboratory

observations indicate that sediment barriers comprised of saline AquaBlok formulations may benefit from such loading.



**Photo 1. Sodium Bentonite-Based Product Hydrated in fresh (left) versus high saline waters (right).**



**Photo 2. Attapulgite-Based Product Hydrated in fresh (left) versus high saline waters (right).**

In this test report, information is presented related to selected, dry and hydrated state characteristics of chosen saline formulations hydrated in either full-strength seawater or in brackish waters. Also presented are data related to the potential effects that loading, either during or after hydration, could ultimately have on the physical characteristics of saline-compatible barriers.

#### Materials and Methods

Several saline formulations were tested, including two attapulgite-based formulations (4060 SW and 5050 SW) and two blended clay formulations (3070 SW and 5050 SW). Each of the blended formulations included equal dry weight percentages of sodium bentonite and attapulgite clay. The core component for all four formulations comprised crushed limestone aggregate nominally equivalent in size and gradation to AASHTO No. 8 aggregate.

Data presented in this report were developed using the same types of testing equipment and generally following the same methods used to obtain similar data for freshwater formulations (see Test Report No. 1 and No. 6).

For current testing, saline product samples were placed in even, single lifts at dry coverage rates ranging from ~ 20 to ~ 60 pounds per square foot (lbs./SF). For most testing, waters with a salinity level equal to typical full-strength seawater (~ 36 parts per thousand, ppt) were used as the hydrating liquid. A commercially available seawater salt mix was used to prepare the testing solutions and a calibrated specific conductance meter (with temperature correction) was used to verify the target salinity (i.e. electrical conductance) level. The chemical composition of the prepared seawater solutions was verified against the composition of typical seawater.

To demonstrate the effect that physical loading could potentially have on the hydrated thickness of saline product and on the relative abundance of residual primary porosity, sand or aggregate was placed overtop several selected samples at loading rates ranging of from ~ 20 to ~ 50 lbs./SF. Loads were applied either immediately following dry product placement or within two to three days after product had had the opportunity to hydrate and expand un-loaded.

Furthermore, to demonstrate the influence of salinity level on product hydration and expansion as a function of clay type, additional testing was conducted involving the use of variable-strength seawater solutions, at target salinity levels of ~ 9, 18, or 36 ppt, to hydrate two selected saline formulations (5050 SW attapulgite and 5050 SW clay blend). For comparison, one selected freshwater (sodium bentonite-based) product formulation (3070 FW) was also tested. For this testing, all formulations were placed at a dry coverage rate of ~20 lbs./SF.



Results

Dry state characteristics are presented in Figure 1. Mean dry and hydrated thickness values in full-strength seawater as a function of formulation and coverage rate, and with or without immediate or delayed loads applied for selected coverage rates, are included in Figures 2A through 2D. Figures 3A through 3C summarize net vertical expansion, wet bulk density, and percent-moisture, respectively, for all saline formulations combined. Mean dry and hydrated thickness values for SW and FW formulations as a function of salinity and coverage rate are included in Figures 4A through 4C.

Selected photographs are also included for a typical series of column tests conducted for a given saline formulation (Photograph 3) and also to illustrate some formulations' apparent physical responses to the influence of immediate versus delayed loading (Photographs 4 through 7).

Figure 1. Typical Density and Porosity Values for Selected Saline Formulations.

Product Formulation	Aggregate Core	Average Partial Density of Dry Product (g/cm <sup>3</sup> )	Approximate Inter-partial Porosity (percent)	Dry Bulk Density, Typical Range (lbs/ft <sup>3</sup> )				
				6 5	7 0	7 5	8 0	8 5
3070 SW attapulgit	No. 8	2.24	48					
4060 SW attapulgit	No. 8	-----	-----					
5050 SW attapulgit	No. 8	1.74	36					
3070 SW clay blend	No. 8	2.38	45					
5050 SW clay blend	No. 8	1.75	32					

Figure 2. Dry and Hydrated Thickness of Saline Formulations as a Function of Coverage Rate and Loading. Hydrating Water Salinity ~36ppt. (no load applied unless noted)

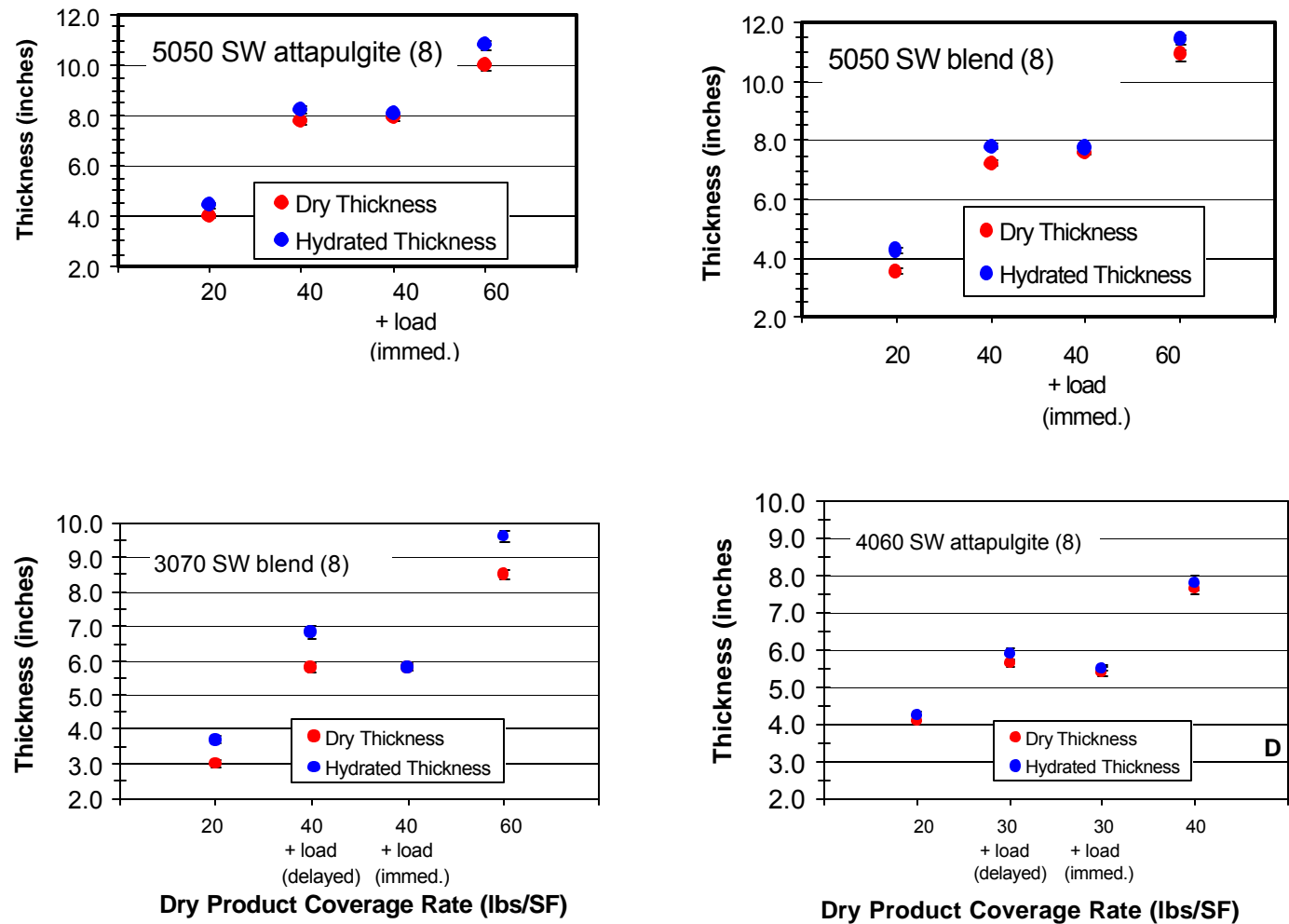


Photo 3. Typical Series of Column Tests.

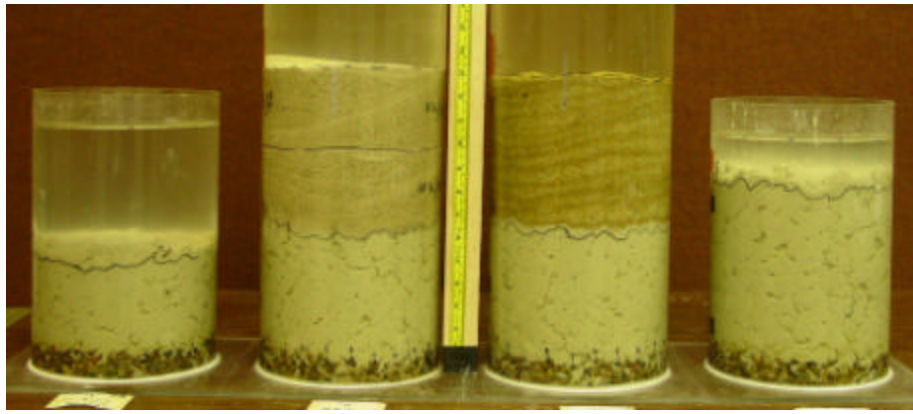


Figure 3. Mean Net Vertical Expansion, Wet Bulk Density, and Percent Moisture of Hydrated Product.

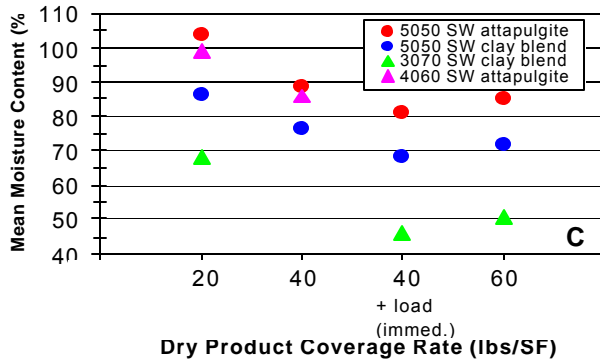
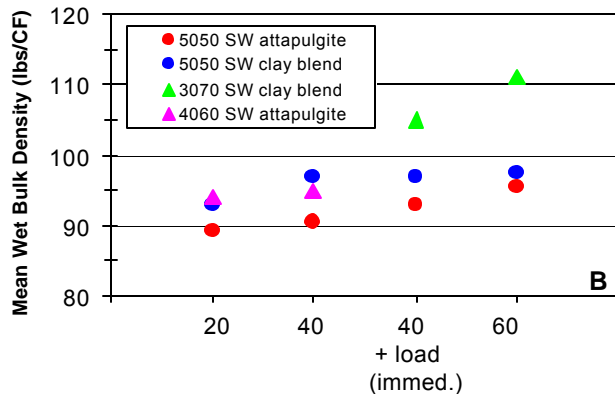
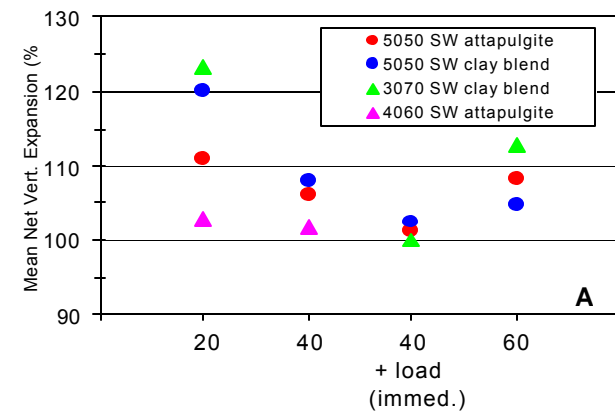
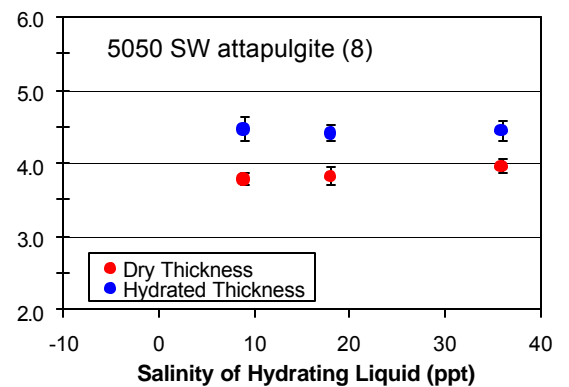
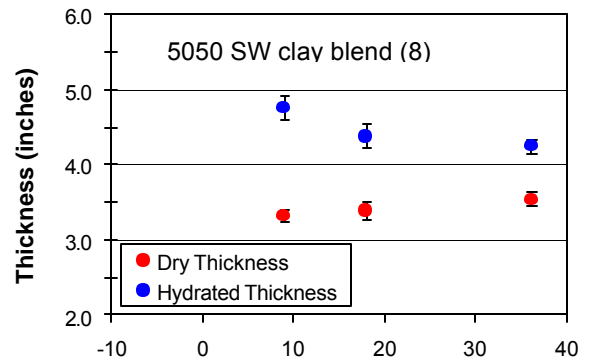
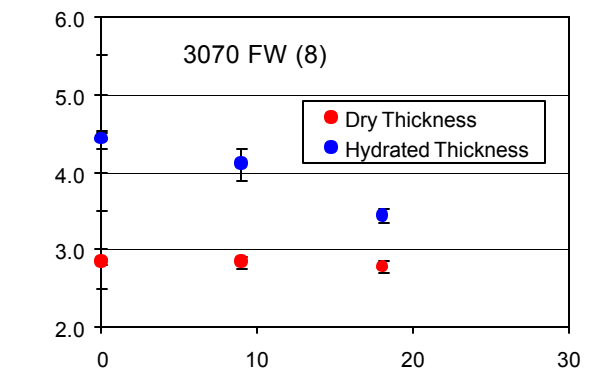


Figure 4. Dry and Hydrated Product Thickness as a Function of Formulation and Salinity of Hydrating Water (dry coverage rate ~20 lbs/SF).



## Observations and Conclusions

Dry particle density and especially dry bulk density values for attapulgite-based materials tend to be somewhat lower than for comparable blended clay formulations (Figure 1), which are, in turn, typically lower than freshwater formulations (see Test Report No. 6). This is probably due to the lower specific gravity of attapulgite, 2.58 g/cc, relative to that for bentonite, 2.82 g/cc (Shackelford 1994).

Once hydrated, saline formulations, particularly attapulgite-based material, display relatively little net vertical expansion in full-strength seawater, as illustrated in Figures 2A through 2D. The low-expansion character of saline formulations in high-saline waters, as summarized in Figure 3A, is especially noteworthy when compared to the significant expansion displayed by freshwater formulations in fresh water (see Figure 3A of Test Report No. 6).

As with dry state characteristics, wet bulk density values for saline formulations also tend to vary as a function of clay type, with attapulgite-based product displaying slightly lower values than comparable blended formulations (Figure 3B). These trends in wet bulk density are accentuated by the lower moisture content of blended product (Figure 3C).

Figure 4 confirms what was conceptually demonstrated in Photographs 1 and 2: that a progressively lower degree of vertical expansion occurs as freshwater product is hydrated with increasingly saline waters (Figure 4A), whereas variable salinity levels have less effect on the expansion of saline formulations, particularly attapulgite-based product (Figures 4B and 4C). The salinity dependent behavior of freshwater formulations is also reflected in greater hydraulic conductivity values when freshwater product is permeated with increasingly saline permeants (see Table 1 of Test Report No. 10).

As expected, hydrating saline product under an immediately placed load greatly minimizes its net vertical expansion, whereas a limited degree of net expansion is observed when saline product is allowed to hydrate two or three days prior to load placement (Figure 2; Photographs 4 through 7).

Previously cited literature implies that loading of capping material may be an appropriate step towards construction of effective saline-product barriers in saline environments. Nevertheless, the optimal *timing* for load placement as well as the extent of loading may depend on a number of factors. For example, in some cases, product compaction encouraged by immediate loading may effectively restrict the flow of hydrating waters into macropore spaces, resulting in a greater abundance of residual porosity, at least over the short term (Photographs 4 and 6). This is in contrast to the significant primary pore infilling which may occur for the same types of saline formulations upon allowing them to first hydrate a few days before loading (Photographs 5 and 7).

The technical and economic advantages of applying sand and/or aggregate loads over saline product, including the most appropriate timing for load placement, are aspects of cap design and construction that should be evaluated on a case-by case basis.



Photo 4. 3070 SW Clay Blend, 40lbs./SF (immediate load).



Photo 5. 3070 SW Clay Blend, 40lbs./SF (delayed load).



Photo 6. 4060 SW Attapulgite, 30lbs./SF (immediate load).



Photo 7. 4060 SW Attapulgite, 30lbs./SF (delayed load).

## Material Selection and Placement

The results presented herein highlight important questions to consider when contemplating design and construction of clay based sediment barriers in impacted brackish or saline sediment environments, including: Which attapulgite-based or blended product formulation should be used at a given site? At what coverage rate should the chosen dry product formulation be placed to achieve a particular target hydrated thickness? Or, should a load be placed overtop the product and, if so, what should the load be (composition and rate) and when should it be applied?

Adequate answers to these and related questions will typically involve a consideration of various factors such as site-specific conditions (e.g. salinity levels, sediment characteristics, ecological attributes, etc.), construction timeframe and sequencing, relative costs for capping materials and placement, etc. The primary consideration, though, is often a clarification of the performance-related results that are sought through sediment capping. For example, if achieving a low-permeability barrier (equal to or less than  $10^{-7}$  cm/s) is the primary performance goal for a particular capping project, then issues such as those discussed in Test Report No. 10 should be considered.

On the other hand, if physical isolation of contaminated sediments from bioturbating benthic organisms is the target performance goal, then hydrated cap thickness may be a principle design consideration (Clarke et al. 2001). This will also require the recognition that, for most saline applications, the target hydrated cap thickness is more-or-less the placed (dry) thickness.

Or, if minimizing cap permeability and benthic isolation are both project goals, then consideration could be given to surcharging hydrating (or hydrated) capping product with an appropriate thickness of granular material, e.g. sand, that is particularly attractive habitat for local benthic communities.

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**TEST REPORT #10****Bench-Scale Hydraulic Conductivity as a Function of Product Formulation and Permeant Salinity****Background and Purpose of Testing**

*In situ* capping is a viable alternative for managing contaminated sediments in various aquatic environments, including fresh, brackish, and saline waters. Creation of a relatively low-permeable barrier is often an important management goal when capping sediments in all such environments.

As illustrated in Test Report No. 9, different formulations of the AquaBlok barrier technology – including those containing sodium bentonite (reactive clay, sodium montmorillonite), attapulgite (a.k.a. palygorskite), or clay blends (sodium bentonite plus attapulgite) – tend to hydrate and expand to varying degrees when exposed to waters of different salinity levels. In addition to differences in *physical* responses, the different product formulations can also display varied *hydraulic* responses as a result of recognized differences in the permeability (hydraulic conductivity) of bentonite and attapulgite based materials to saline waters (e.g. Stern and Shackelford, 1998; Tobin and Wild, 1986; Day, 1994). An understanding of the salinity environment into which the capping material is being placed is critical to determining the most appropriate formulation, and coverage rate, required to achieve a target thickness and permeability for a proposed cap.

The permeability of some clay based environmental barriers can also depend on the *stage* or *sequence* at which saline waters are permeated. For example, the hydraulic conductivity of sodium bentonite-based materials to saline waters can be significantly lower, at least in the short term, if the material is first hydrated and permeated with freshwater (Lin and Benson, 2000; Shackelford, 1994). This and other factors should be considered when determining the most appropriate product formulation for site use – and even the best timing for product placement – in that many impacted coastal (estuarine) environments display significant spatial and temporal variability in salinity levels.

Summarized in this test report are hydraulic conductivity values determined for selected freshwater and saline (attapulgite- or clay blend-based) product formulations permeated with waters of either constant or variable salinity over time.

**Methods**

Representative samples of selected freshwater (FW) and saline (SW) formulations ( $n = 1$  for each formulation) were permeated with waters of different salinity levels in the laboratory using flexible-wall permeameters (constant head).

Testing was conducted in general conformance with ASTM Method D5084, as was freshwater product testing (see Test Report No. 3). Cell pressures during testing ranged from approximately 10 to 40 psi and hydraulic gradients were varied from less than 5 cm/cm to slightly over 30 cm/cm.

Samples tested included a number of selected FW or SW formulations manufactured using different clay types (sodium bentonite, attapulgite, or a clay blend); different clay to aggregate weight ratios (2080 to 5050); and a couple different aggregate sizes and gradations. Additional testing details are provided in Tables 1 and 2.

Permeant (input) salinity values ranged from 0 parts per thousand, ppt (de-aired tap water), up to approximately 36 ppt, which is equivalent to that of typical undiluted, or full-strength, seawater. When testing freshwater formulations, Input salinity values were held constant at 0, 8 to 9, and approximately 18 ppt (Table 1). Values were held constant at approximately 36 ppt when testing saline formulations (Table 2). A commercially available seawater salt mix was used to prepare saline solutions at target levels and a calibrated specific conductance meter (with temperature correction) was used to verify target levels. The chemical composition of the prepared seawater solutions was verified against the known composition of typical seawater.

In addition to conducting flexible-wall permeameter testing, a series of rigid-wall permeameter tests (falling head) were also conducted on several selected formulations using permeants containing variable salinity levels over time. Testing was conducted in general accordance with accepted methodology and procedures. Multiple pore volumes of first full-strength seawater then freshwater were continuously passed through each of several different clay rich formulations (5050 FW, 5050 SW attapulgite, and 5050 SW clay blend) over an approximately 30 to 40-day period. The electrical conductivity of volumes of discharge waters emanating from the base of each column was also tracked during testing.

**Results**

Flexible-wall permeameter values for selected FW product formulations permeated with waters of different yet constant salinity levels, and at different hydraulic gradients, are presented in Table 1. Values for selected SW formulations permeated with full-strength seawater, also at different gradients, are presented in Table 2.

Results of rigid-wall permeameter testing of different FW and SW formulations using permeants of variable input salinity over time are portrayed in Figures 1 through 3.

**Table 1****Hydraulic Conductivity of Selected Freshwater AquaBlok Formulations as a Function of Permeant Salinity and Hydraulic Gradient**

Freshwater Product Formulation <sup>1, 2</sup>	Approx. Permeant Salinity (ppt)	Hydraulic Conductivity as a Function of Hydraulic Gradient (in units of cm/cm)						
		<5	5-10	10-15	15-20	20-25	25-30	>30
2080 FW	0	--	--	--	--	$8.1 \times 10^{-9}$ <sup>4</sup>	--	--
	8 <sup>3</sup>	$4.0 \times 10^{-8}$	$5.7 \times 10^{-8}$	--	--	--	--	--
	9	--	$5.4 \times 10^{-8}$	$6.6 \times 10^{-8}$	--	$6.5 \times 10^{-8}$	--	$6.2 \times 10^{-8}$
	18	--	$1.0 \times 10^{-6}$	$1.7 \times 10^{-6}$	$5.9 \times 10^{-6}$	--	$6.0 \times 10^{-6}$	$6.0 \times 10^{-6}$
3070 FW	8 <sup>3</sup>	$1.3 \times 10^{-8}$	$1.2 \times 10^{-8}$	--	--	--	--	--

**Footnotes:**

1. "2080 or "3070" indicates relative percentages of clay and aggregate, by dry weight. "FW" indicates a freshwater (sodium bentonite-based) product.
2. Aggregate used to prepare product nominally equivalent in size gradation to AASHTO No. 8 aggregate.
3. Permeant liquid comprised of relatively calcium- and chloride-rich wastewater (i.e. pond water from a specific project).
4. Please see Test Report No. 3 for additional conductivity data derived by permeating fresh water through various FW product formulations.



Table 2

**Hydraulic Conductivity of Selected Saline AquaBlok Formulations to Full-Strength (~36 ppt) Seawater as Function of Hydraulic Gradient**

Clay Type in Sealant Layer	Saline Product Formulation <sup>1, 2</sup>	Hydraulic Conductivity as a Function of Hydraulic Gradient (units of cm/cm)						
		<5	5-10	10-15	15-20	20-25	25-30	>30
Attapulgite (palygorskite)	3070 SW	$5.9 \times 10^{-5}$	--	--	$3.1 \times 10^{-5}$	--	$1.4 \times 10^{-5}$	--
	4060 SW	--	$1.6 \times 10^{-7}$	--	$3.2 \times 10^{-7}$	--	$4.0 \times 10^{-6}$	--
	5050 SW	--	$7.8 \times 10^{-8}$	$8.6 \times 10^{-8}$	--	$8.3 \times 10^{-8}$	$3.1 \times 10^{-7}$	--
	5050 SW <sup>3</sup>	--	--	--	$7.0 \times 10^{-8}$	--	--	--
Clay Blend	3070 SW	--	$7.5 \times 10^{-8}$	--	$7.6 \times 10^{-8}$	--	$1.0 \times 10^{-7}$	--
	5050 SW	--	$4.9 \times 10^{-8}$	--	$4.8 \times 10^{-8}$	--	$5.3 \times 10^{-8}$	--

## Footnotes:

1. "5050" or "2080" indicates relative percentages of clay and aggregate, by dry weight. "SW" indicates a saline (attapulgite or clay blend) product formulation.

2. Unless noted otherwise, aggregate used to prepare product nominally equivalent in size gradation to AASHTO No. 8 aggregate.

3. Aggregate core comprises a blend of equal quantities of nominal AASHTO No. 8 and No. 57 aggregate.

## Observations and Conclusions

### Flexible-Wall Permeameter Testing Results

Although low permeability values ( $10^{-8}$  to  $10^{-9}$  cm/s) can be achieved when permeating freshwater formulations with fresh and even brackish waters, higher flow (as high as  $10^{-5}$  cm/s) tends to occur when the same formulations are permeated with higher-saline waters (Table 1). This phenomenon has generally been observed by others (e.g. Stern and Shackelford, 1998; Stewart et al., 2003; Day, 1994) and illustrates the relative sensitivity and physical instability of sodium bentonite (montmorillonite) in higher-saline environments, particularly in terms of the clay's tendency to flocculate in the presence of high concentrations of salts, which leads to increased effective porosity and, ultimately, increased permeability.

Nevertheless, because permeability values equal to or less than  $10^{-7}$  cm/s are considered appropriate for different types of clay based barriers in a variety of environmental applications (Tobin and Wild, 1986; Sallford and Hogsta, 2002; US EPA, 1998; Dunn and Palmer, 1994), data in Table 1 also imply that some FW formulations - particularly those relatively enriched in clay - can be used to create appropriate, effective hydraulic barriers in brackish waters with salinity levels of up to at least 8 or 9 ppt. The appropriateness of using FW formulations - rather than SW formulations - to meet project-specific goals in impacted brackish/estuarine, or even wastewater-pond, environments should be evaluated on a project-specific basis.

In contrast to the relative sensitivity of FW formulations to higher saline permeants, the permeability of attapulgite-based materials - particularly those with relatively high clay content - typically remain at or below  $10^{-7}$  cm/s when permeated with full-strength seawater solutions (Table 2). Similarly low permeability values are also seen when attapulgite-based product is permeated with less saline waters, including freshwater (data not shown). The current work also indicates that relatively higher permeability values, up to  $10^{-5}$  cm/s, may occur for less clay rich, attapulgite-based formulations when infiltrated with full-strength seawater (Table 2). Nevertheless, the relative physical and hydraulic insensitivity (stability) of attapulgite-based materials to salts and other chemically aggressive solutions (organic leachates, acidic solutions, etc) - in contrast to the relative sensitivity and instability displayed by many bentonite-based materials to such permeants - has been noted by others (Shackelford, 1994; Galan, 1996; Tobin and Wild, 1986).

Physical loading of saline formulations (during or following hydration) may have a positive influence on reducing barrier permeability by reducing residual porosity through

compression or compaction of the hydrating/hydrated material mass (see Test Report No. 9).

As also indicated in Table 2, permeameter values for formulations manufactured using a *blend* of clays and permeated with full-strength seawaters are also relatively low, on the order of  $10^{-8}$  cm/s. Similarly low values were also observed when lower-salinity waters, including freshwater, were used as the permeant (data not shown). However similar, test results for blended formulations (Table 2) appear to differ from results for attapulgite-based formulations in two important respects: (1) values for relatively clay rich, blended formulations (e.g. 5050 SW) appear to be somewhat lower than for similar, attapulgite-based formulations and (2) values for less clay rich, blended formulations (i.e., the 3070 SW formulation) are up to several orders of magnitude lower than for similar, attapulgite-based formulations.

The positive effect that blending attapulgite with sodium bentonite can have on the physical as well as hydraulic stability of environmental barrier materials in high salinity systems and in other chemically aggressive environments has been recognized by others (e.g. Murray 2000; Stern and Shackelford, 1998).

### Rigid-wall Permeameter Testing Results

Results of rigid-wall permeameter testing of selected FW and SW formulations generally corroborate results of flexible-wall testing (Figures 1 through 3). Recognized differences in equipment, testing methodologies, etc. usually preclude direct, quantitative comparisons of the two types of data, and it is generally accepted that rigid-wall tests tend to overestimate hydraulic conductivity values (Shackelford, 1994), as also seen herein.

As illustrated through flexible-wall testing, rigid-wall results once again generally reflect the relatively high sensitivity of sodium bentonite-based materials to permeants of variable salinity (Figure 1) in contrast to the relative insensitivity, or stability, of attapulgite-bearing materials to the same, temporally variable permeants (Figure 3). Blended clay formulations tend to display an intermediate hydraulic response (Figure 2).

To summarize, attapulgite- or blended clay based formulations of the AquaBlok product are as appropriate for use within saline environments as are bentonite-based formulations for use at freshwater sites. And although not typically applicable to higher salinity environments, some bentonite-based formulations can also be effective in some brackish environments. The level of appropriateness will depend on a number of factors (spatial and temporal ranges in salinity values; prevailing surface-water salinity

Figure 1. Testing of 5050 FW (poorly graded)

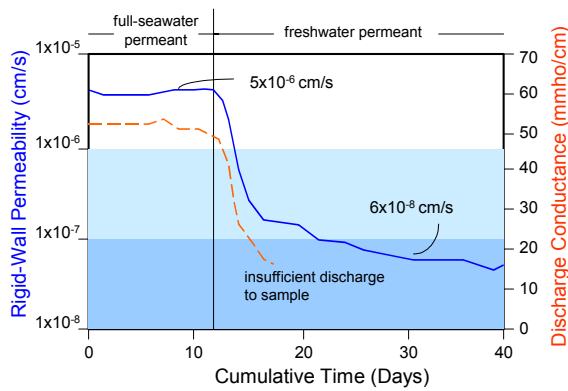


Figure 2. Testing of 5050 SW Clay Blend (poorly graded)

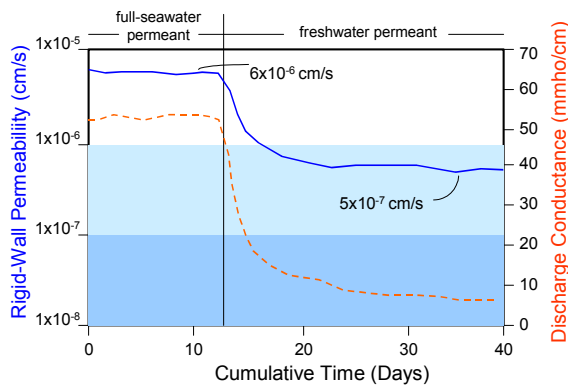
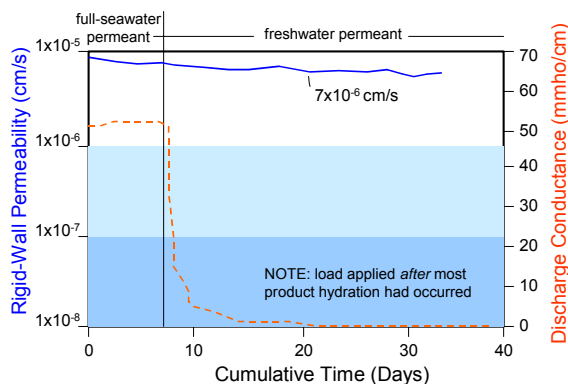


Figure 3. Testing of 5050 SW Attapulgite (poorly graded)



values during product placement; target cap thickness; etc.) and should be evaluated on a case by case basis.

Furthermore, if achieving a particular, target permeability value is a primary goal for remedial cap performance at a specific saline site, then the most appropriate saline formulation for use in the project could involve a number of additional considerations, including: allowable tolerance range for meeting the target value; an understanding of the relationship between water-column salinity and water depths, including whether or not a significant salt wedge periodically occurs at the site and when/where the wedge occurs; target cap design and relative product costs; etc.

## Material Selection

Results presented herein indicate that blended clay formulations (rather than attapulgite-based product) are probably more appropriate for use in sediment cap designs for most full-seawater environments; surcharging with sand or aggregate loads,

either during or after product hydration, may help consolidate barrier material and increase its ultimate effectiveness. Relatively clay rich, attapulgite-based formulations may also be effective in some full-seawater systems, and could be more appropriate than blended product for use in other chemically aggressive environments, depending on the dissolved or pure-phase contaminants involved.

The laboratory data and literature presented herein also imply that, although sodium bentonite-based product is not usually appropriate for typical full-seawater environments, it could, in fact, be effective and appropriate for barrier construction in estuarine environments, where significant spatial and temporal variability exists in salinity levels, and where adequate "windows" of less saline (and more brackish) waters may occur during which the freshwater product could be applied. The appropriateness of applying sodium bentonite-based product in saline or brackish environments should be evaluated on a case by case basis.

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You can also email us at: [services@aquablokinfo.com](mailto:services@aquablokinfo.com) or visit us at our web site at: [www.aquablokinfo.com](http://www.aquablokinfo.com)

Last Revised 01/14/05

# ORGANOCLAY REACTIVE CORE MAT™

MATERIAL PROPERTY	TEST METHOD	VALUE
ORGANOCLAY <sup>1</sup>		
Bulk Density Range	CETCO Test Method	44 – 56 lbs/ft <sup>3</sup>
Oil Adsorption Capacity	CETCO Test Method	0.5 lb of oil per lb of organoclay, minimum
Quaternary Amine Content	CETCO Test Method	25 – 33% quaternary amine loading
FINISHED RCM PRODUCT		
Organoclay Mass per Area	CETCO Test Method	0.8 lb/ft <sup>2</sup>
Mat Grab Strength <sup>2</sup>	ASTM D4632	90 lbs. MARV
Hydraulic Conductivity <sup>3</sup>	Mod. ASTM D4491	1 x 10 <sup>-3</sup> cm/sec minimum

## Notes

- <sup>1</sup> Organoclay properties performed periodically on material prior to incorporation into the RCM.  
<sup>2</sup> All tensile testing is performed in the machine direction.  
<sup>3</sup> Permittivity at constant head of 2 inches and converted to hydraulic conductivity using Darcy's Law and RCM thickness per ASTM D5199 for geotextiles.

A permeable composite of geotextiles and a non-swelling granular clay compound that reliably adsorbs oil and similar organics from water.

Roll Size: 15' x 100'

Packaged on 4" PVC core tubes, and wrapped with polyethylene plastic packaging.



1500 West Shure Drive 5th Floor, Arlington Heights, IL 60004 USA 800.527.9948 Fax 847.577.5566

For the most up-to-date product information please visit our website, [www.sedimentremediation.com](http://www.sedimentremediation.com)

A wholly owned subsidiary of AMCOL International Corporation

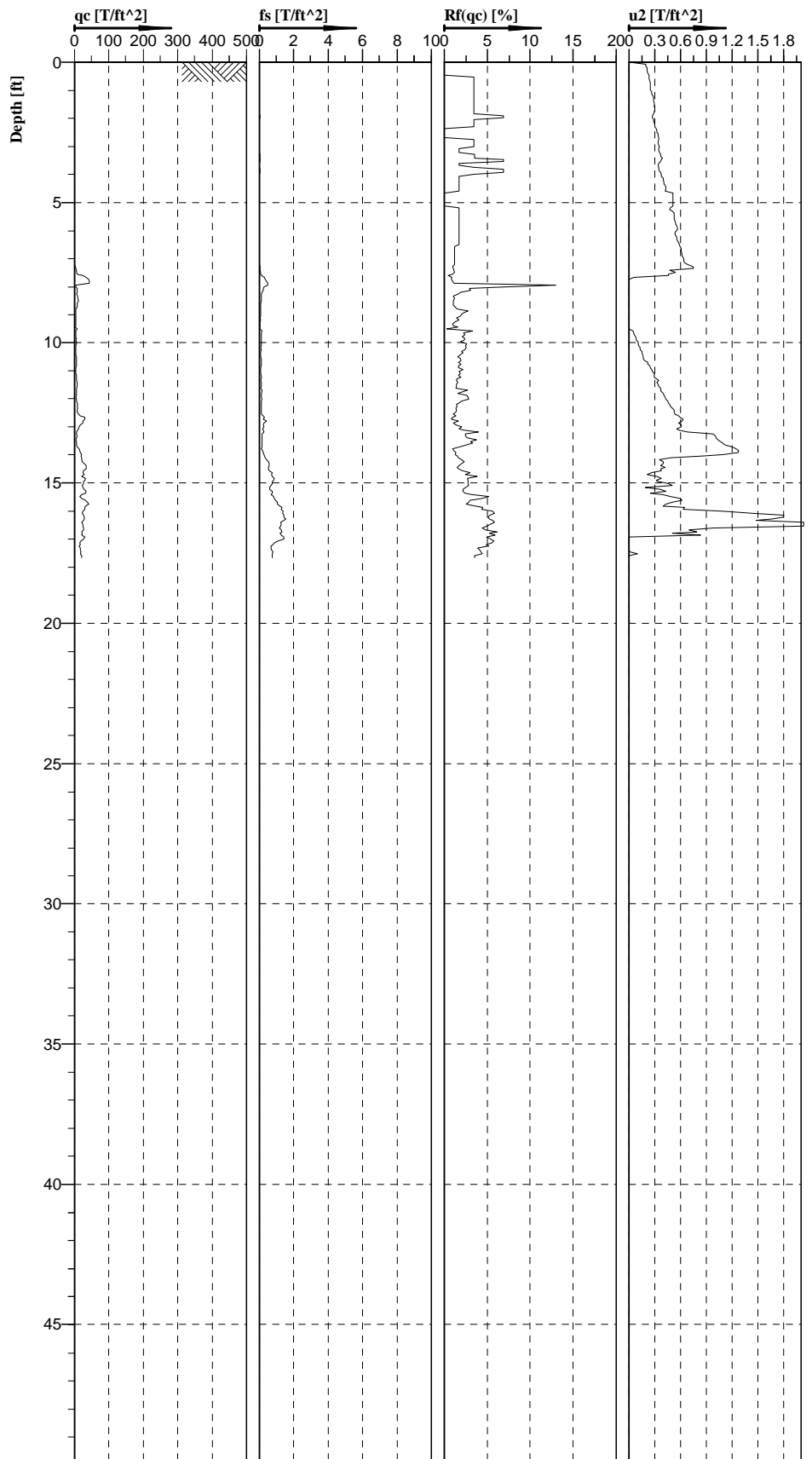
The information and data contained herein are believed to be accurate and reliable, CETCO makes no warranty of any kind and accepts no responsibility for the results obtained through application of this information.

## Cone Penetrometer Testing Logs

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**Classification by  
Robertson 1986**

Sensitive fine grained (1)  
Organic material (2)  
Sensitive fine grained (1)  
Sensitive fine grained (1)  
Sensitive fine grained (1)  
Clayey silt to silty clay (5)  
Sensitive fine grained (1)  
Clay (3)  
Sensitive fine grained (1)  
Clayey silt to silty clay (5)  
Sandy silt to clayey silt (6)  
Clay (3)

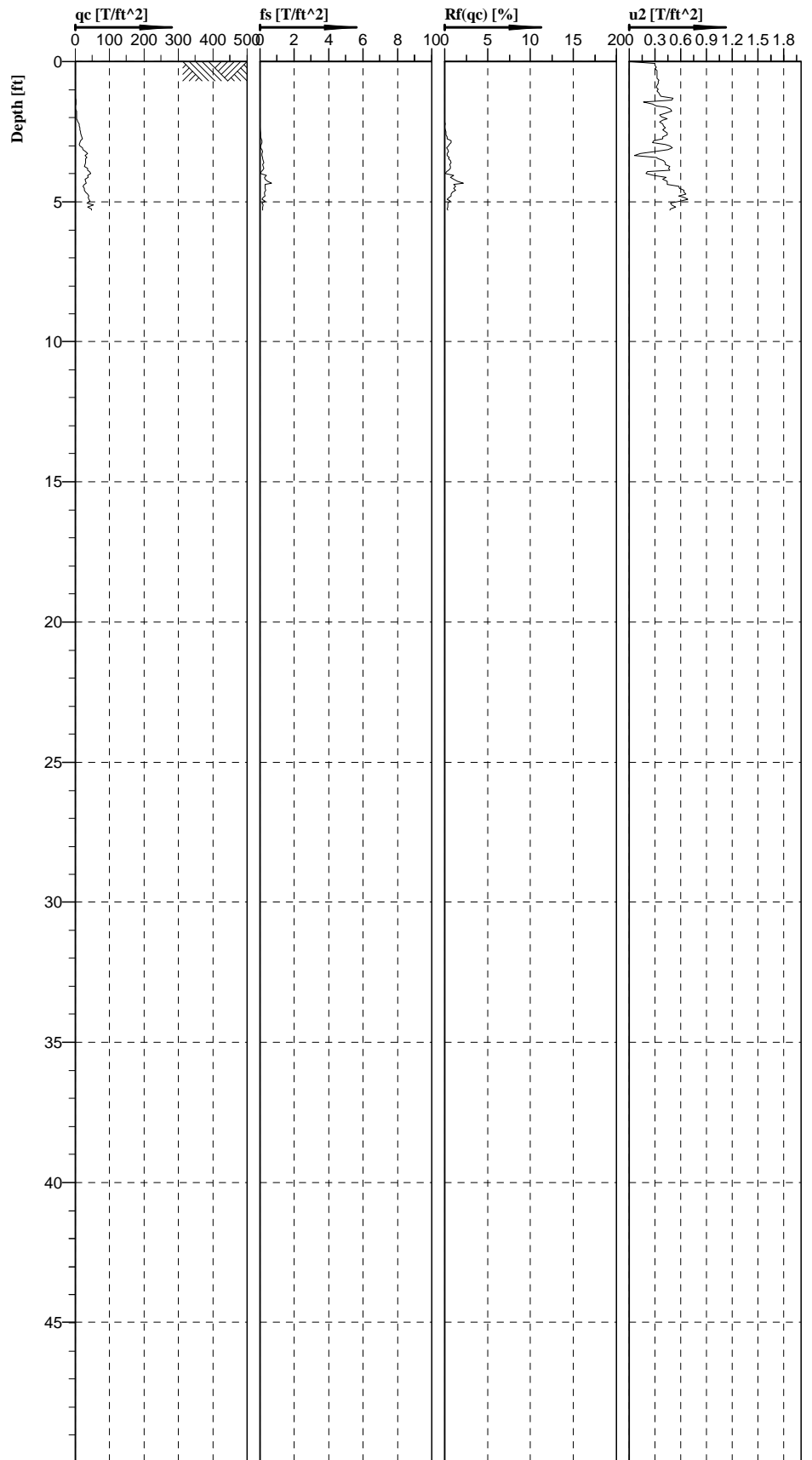


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Tip area [cm<sup>2</sup>]: 10  
Sleeve area [cm<sup>2</sup>]: 150

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Project ID: 389462	Client: CH2M HILL	Date: 5/18/2009	Scale: 1 : 70
Project: HILLCPT1		Page: 1/1	Fig:
		File: hillcpt1.cpd	

Classification by  
Robertson 1986

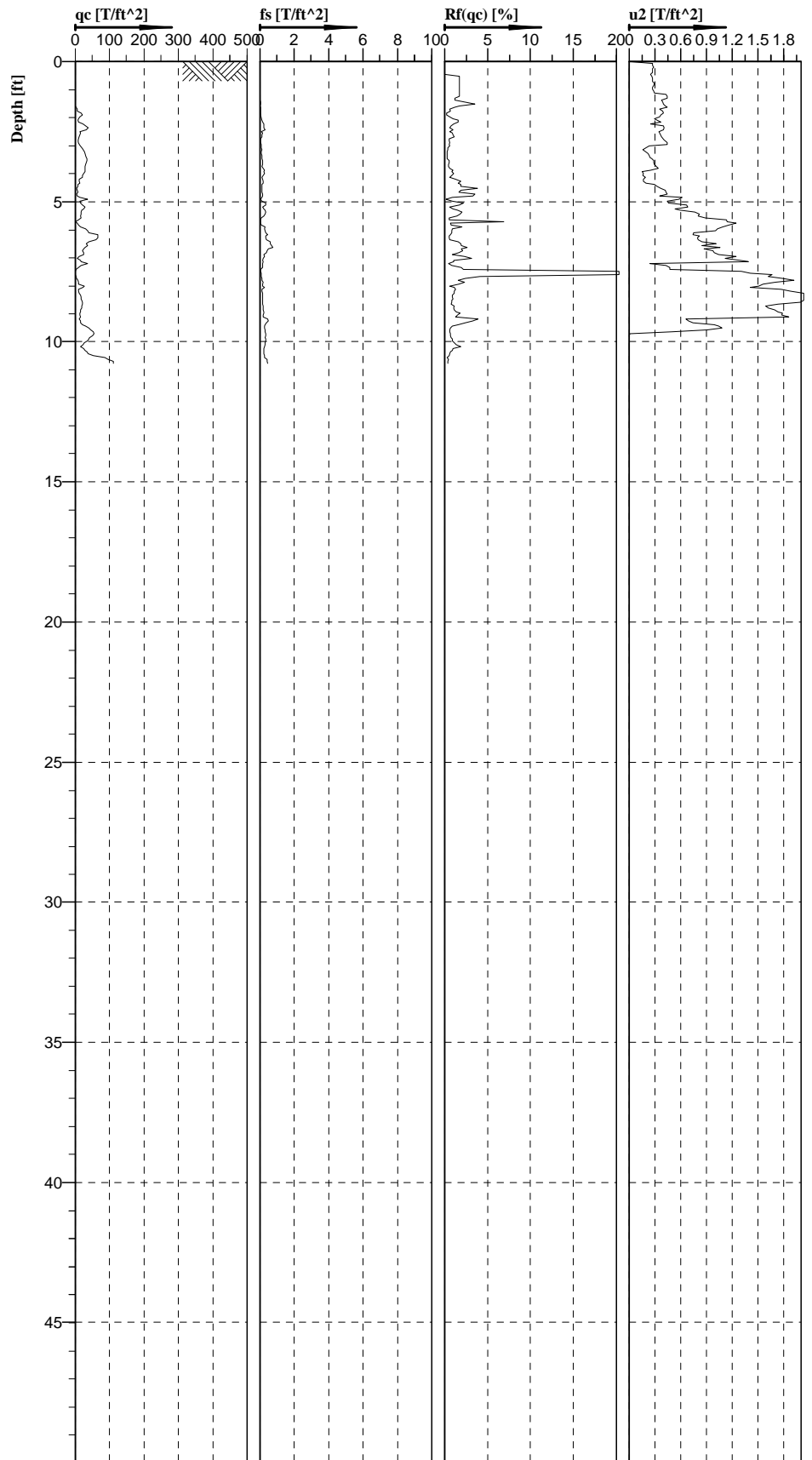
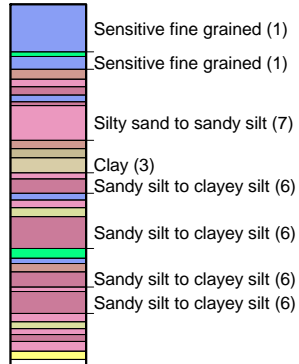
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Silty sand to sandy silt (7)  
Silty sand to sandy silt (7)



Cone No: 3933  
Tip area [cm<sup>2</sup>]: 10  
Sleeve area [cm<sup>2</sup>]: 150

Location: Penuelas, PR	Position: X: 0.00 ft, Y: 0.00 ft	Ground level: 0.00	Test no: HILLCPT2
Project ID: 389462	Client: CH2M HILL	Date: 5/18/2009	Scale: 1 : 70
Project: HILLCPT2		Page: 1/1	Fig:
SWMU 5 Phase 1 Field Work, UCCLLC Penuelas, PR		File: hillcpt2.cpd	

**Classification by  
Robertson 1986**



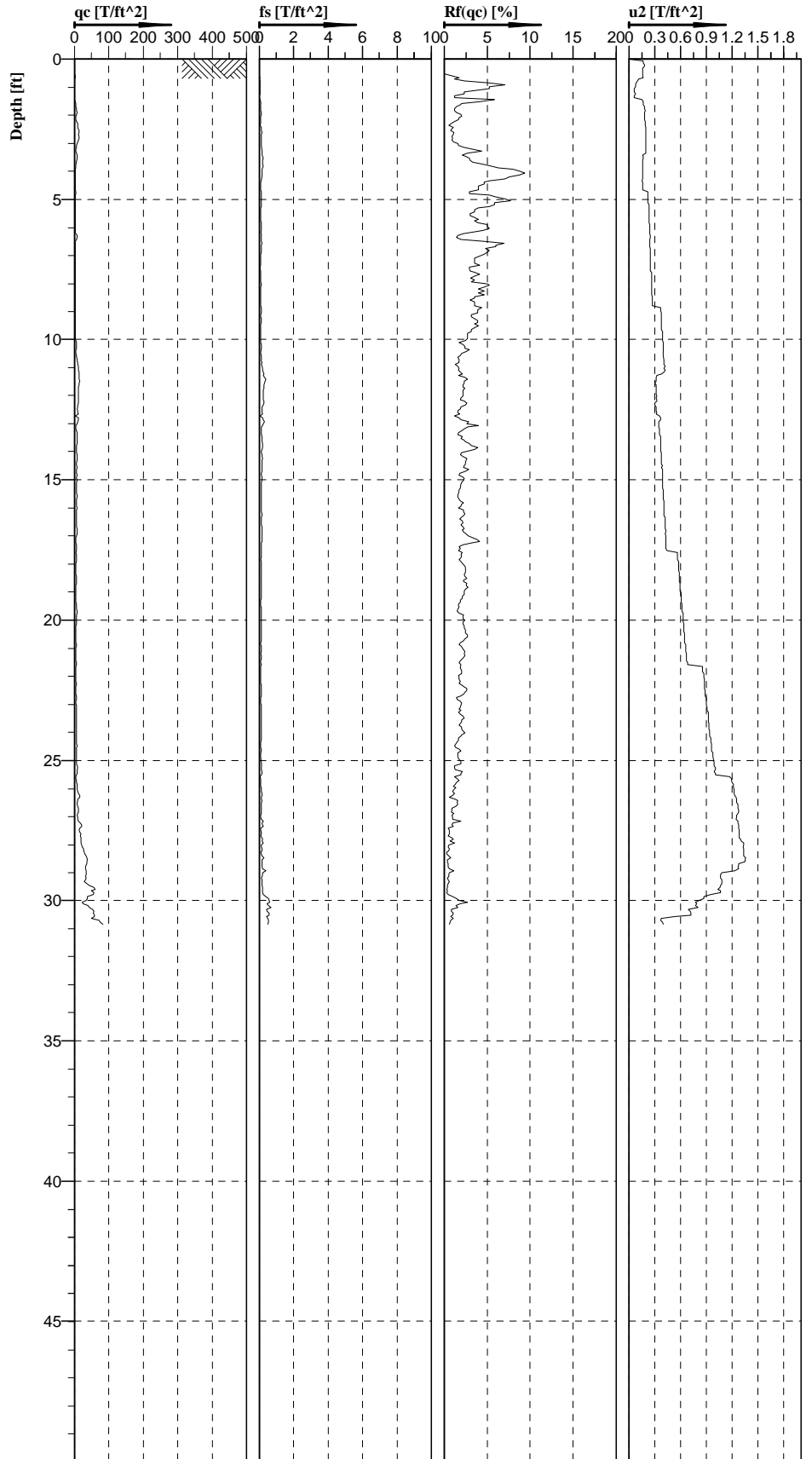
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Sleeve area [cm<sup>2</sup>]: 150

Location: Penuelas, PR	Position: X: 0.00 ft, Y: 0.00 ft	Ground level: 0.00	Test no: HILLCPT2A
Project ID: 389462	Client: CH2M HILL	Date: 5/18/2009	Scale: 1 : 70
Project: HILLCPT2A		Page: 1/1	Fig:
SWMU 5 Phase 1 Field Work, UCCLLC Penuelas, PR		File: hillcpt2A.cpd	



**Classification by  
Robertson 1986**

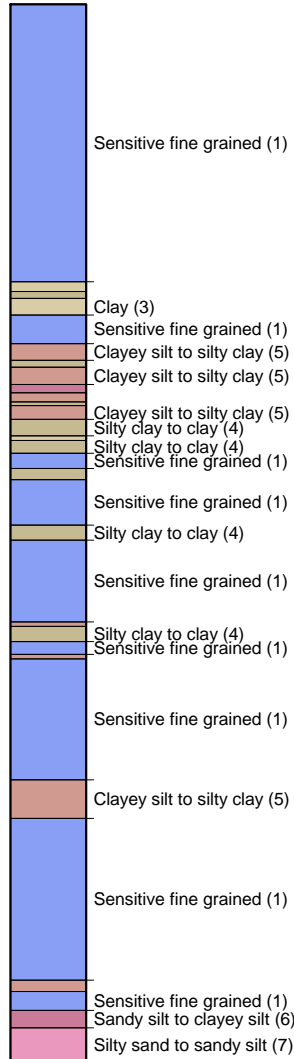
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 Organic material (2)  
 Sensitive fine grained (1)  
 Sandy silt to clayey silt (6)  
 Organic material (2)  
 Clay (3)  
 Organic material (2)  
 Clay (3)  
 Clay (3)  
 Clayey silt to silty clay (5)  
 Silty clay to clay (4)  
 Silty clay to clay (4)  
 Clay (3)  
 Sensitive fine grained (1)  
 Silty clay to clay (4)  
 Clay (3)  
 Silty clay to clay (4)  
 Sensitive fine grained (1)  
 Sensitive fine grained (1)  
 Silty clay to clay (4)  
 Sensitive fine grained (1)  
 Clayey silt to silty clay (5)  
 Sensitive fine grained (1)  
 Sandy silt to clayey silt (6)  
 Silty sand to sandy silt (7)  
 Sand to silty sand (8)  
 Silty sand to sandy silt (7)  
 Sand to silty sand (8)



Cone No: 3933  
 Tip area [cm2]: 10  
 Sleeve area [cm2]: 150

Location: Penuelas, PR	Position: X: 0.00 ft, Y: 0.00 ft	Ground level: 0.00	Test no: HILLCPT3
Project ID: 389462	Client: CH2M HILL	Date: 5/18/2009	Scale: 1 : 70
Project: HILLCPT3		Page: 1/1	Fig:
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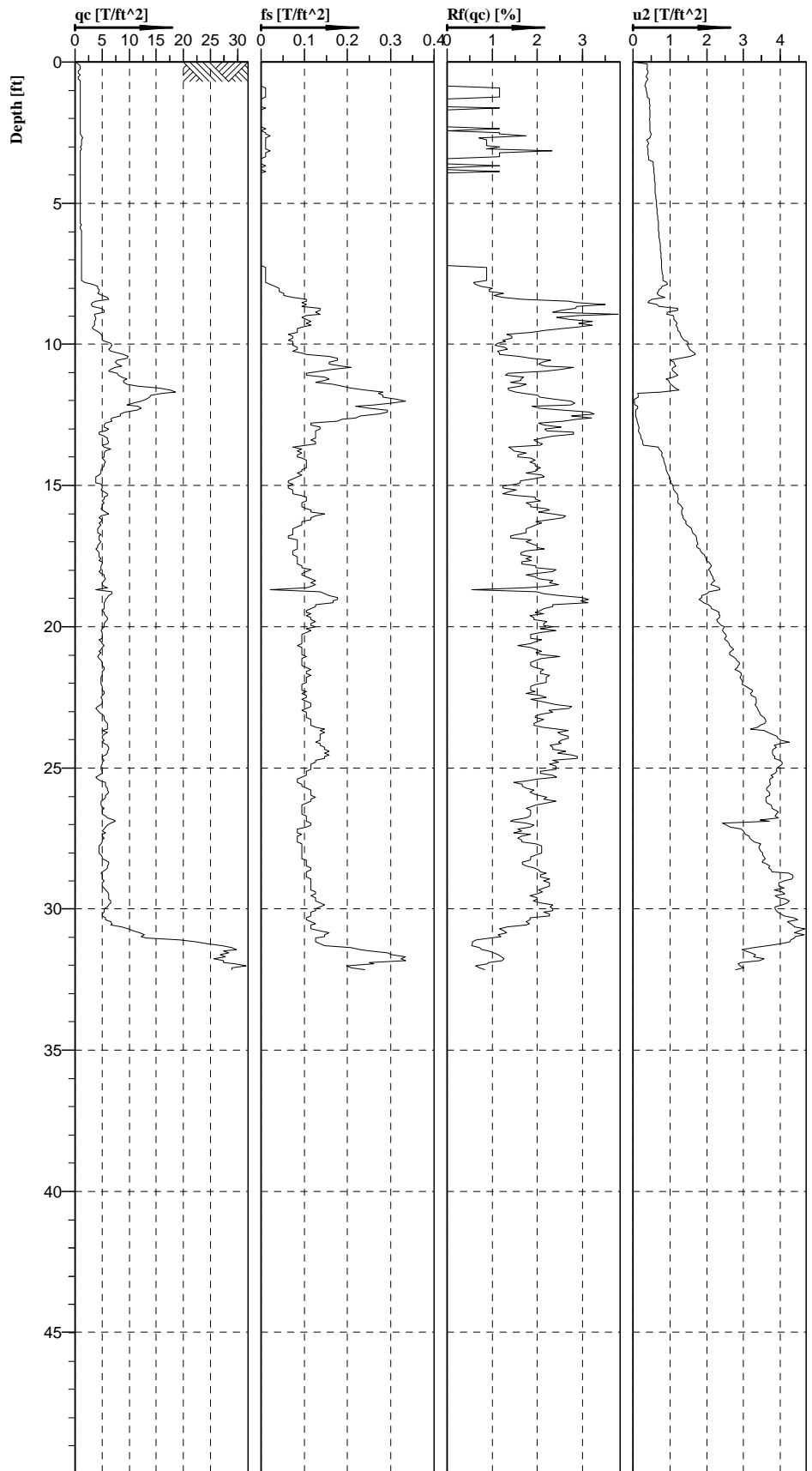
Classification by  
Robertson 1986



Surface of Water

11.5'

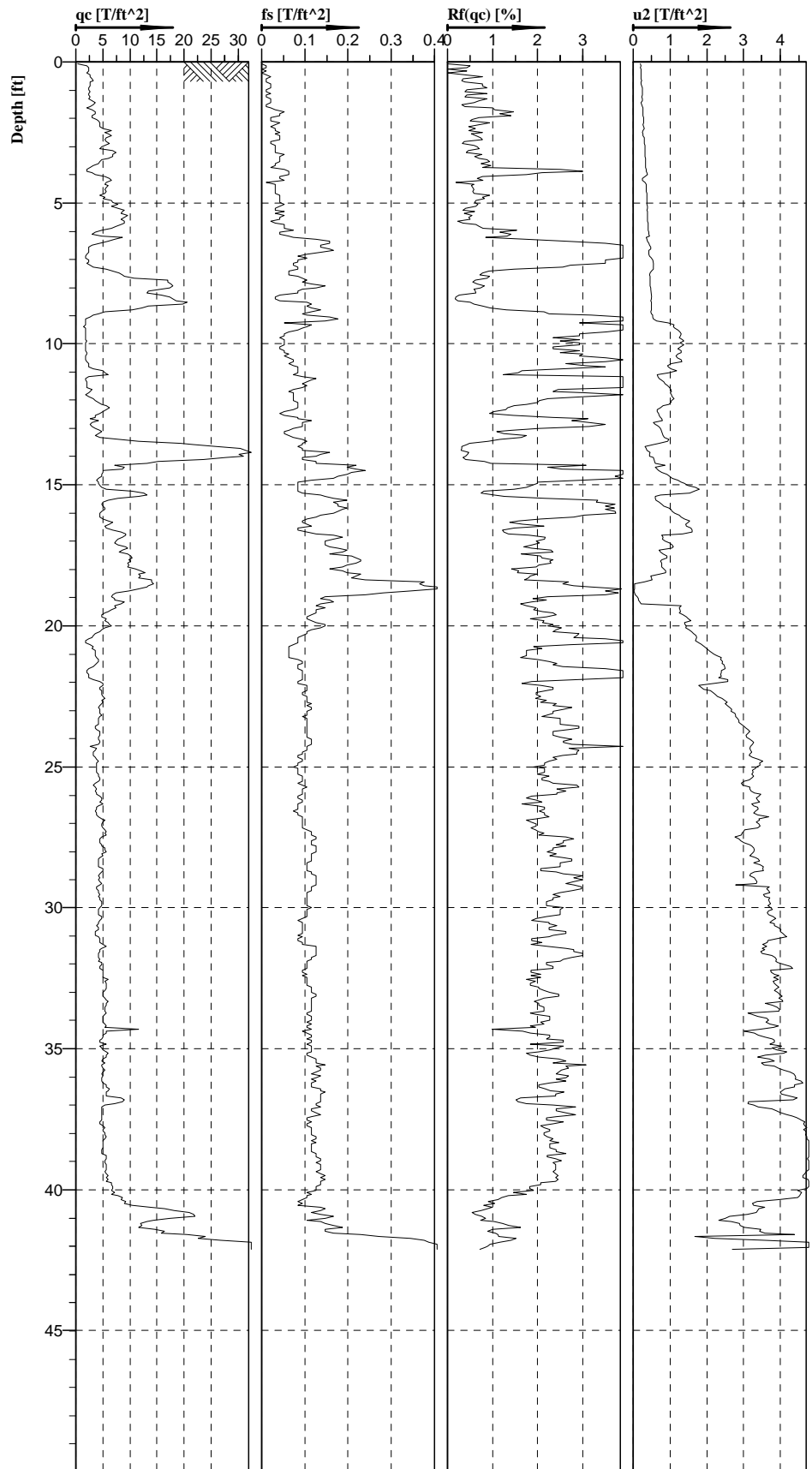
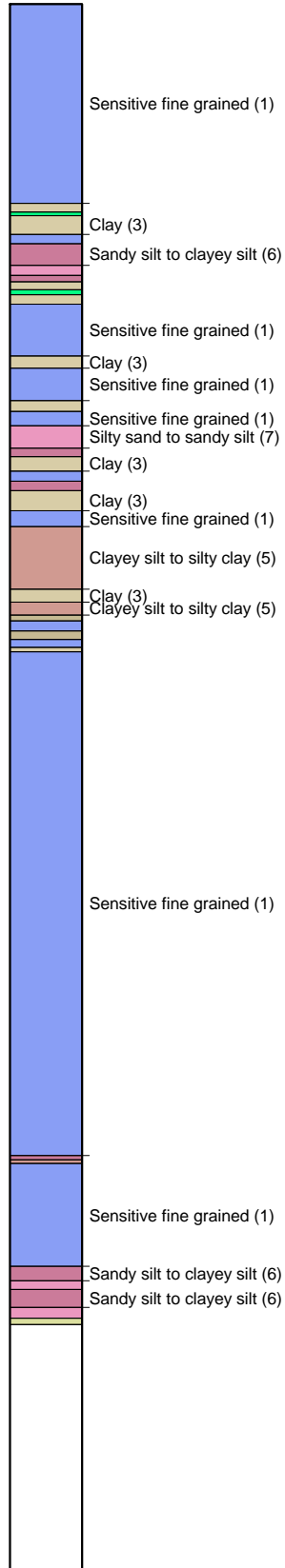
Sediment



Cone No: 3933  
Tip area [cm<sup>2</sup>]: 10  
Sleeve area [cm<sup>2</sup>]: 150

Location: Penuelas, PR	Position: X: 0.00 ft, Y: 0.00 ft	Ground level: 0.00	Test no: HILLCPT4
Project ID: 389462	Client: CH2M HILL	Date: 5/19/2009	Scale: 1 : 70
Project: HILLCPT4		Page: 1/1	Fig:
SWMU 5 Phase 1 Field Work, UCCLLC (14'-2.5'=11.5')		File: hillcpt4.cpd	

Classification by  
Robertson 1986



Cone No: 3933  
Tip area [cm<sup>2</sup>]: 10  
Sleeve area [cm<sup>2</sup>]: 150

Location: Penuelas, PR	Position: X: 0.00 ft, Y: 0.00 ft	Ground level: 0.00	Test no: HILLCPT5
Project ID: 389462	Client: CH2M HILL	Date: 5/19/2009	Scale: 1 : 70
Project: HILLCPT5		Page: 1/1	Fig:
SWMU 5 Phase 1 Field Work, UCCLLC		File: hillcpt5_recovered.CPT	

# ZEBRA CPT Field Book

CH2M Hill	Penuelas, PR						
Number of Days CPT	2	1				2	
Weather		Sunny				Sunny	
DEPTH for DAY		65				75	
DATE		5/18/2009	5/18/2009	5/18/2009	5/18/2009	5/19/2009	5/19/2009
Number of locations	6	HILLCPT1	HILLCPT2	HILLCPT2A	HILLCPT3	HILLCPT4	HILLCPT5
CPT Unit		Barge	Barge	Barge	Barge		
CPT Probe #3993	140	18	5	11	31	33	42
			Refusal				
Total Depth	139.6						
Response Test Result							
Sampling Setup Below		Location Notes	Location Notes	Location Notes	Location Notes	Location Notes	Location Notes
BARAGE DECK 2.5' Above Water Surface		2.5 ft.	2.5 ft.	2.5 ft.	2.5 ft.	2.5 ft.	2.5 ft.
Water Depth to Sediment		5 ft.	8.5 ft.	8.5 ft.	4.5 ft.	11.5 ft.	5.5 ft.
SEDIMENT		17.6 ft.	Refusal 5 ft.	11 ft.	31 ft.	33 ft.	42 ft.

# ZEBRA CPT Field Book

CH2M Hill	Penuelas, PR						
Number of Days CPT	2						
Weather							
DEPTH for DAY							
DATE							
Number of locations	6						
CPT Unit							
CPT Probe #3993	140						
Total Depth	139.6						
Response Test Result							
Sampling Setup Below							
BARAGE DECK 2.5' Above Water Surface							
Water Depth to Sediment							
SEDIMENT							

# ZEBRA CPT Field Book

CH2M Hill	Penuelas, PR								
Number of Days CPT	2								
Weather									
DEPTH for DAY									
DATE									
Number of locations	6								
CPT Unit									
CPT Probe #3993	140								
Total Depth	139.6								
Response Test Result									
Sampling Setup Below									
BARAGE DECK 2.5' Above Water Surface									
Water Depth to Sediment									
SEDIMENT									

# ZEBRA CPT Field Book

CH2M Hill	Penuelas, PR					
Number of Days CPT	2					
Weather						
DEPTH for DAY						
DATE						
Number of locations	6					
CPT Unit						
CPT Probe #3993	140					
Total Depth	139.6					
Response Test Result						
Sampling Setup Below						
BARAGE DECK 2.5' Above Water Surface						
Water Depth to Sediment						
SEDIMENT						